CROSS-SECTIONAL AND LONGITUDINAL RELATIONSHIPS BETWEEN PHYSICAL ACTIVITY AND HEALTH SERVICES UTILIZATION IN COMMUNITY-DWELLING OLDER ADULTS

A Thesis Submitted to the College of Graduate Studies and Research in Partial Fulfillment
of the Requirements for the Degree of Doctor of Philosophy in the
College of Kinesiology

University of Saskatchewan

Saskatoon, Saskatchewan

By

Koren Lea Fisher

PERMISSION TO USE

In presenting this dissertation in partial fulfillment of the requirements for a Doctor of Philosophy degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this dissertation in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis/dissertation work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this dissertation or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my dissertation.

Requests for permission to copy or to make other uses of materials in this thesis/dissertation in whole or part should be addressed to:

Dean of the College of Kinesiology
University of Saskatchewan
87 Campus Drive
Saskatoon, Saskatchewan S7N 5B2
CANADA

ABSTRACT

There has been a growing interest among policymakers in the potential role of physical activity (PA) as a strategy to mitigate the challenges associated with an aging population, specifically the potential pressures on the health care system presented by an increasing need and demand for long term management of chronic health conditions. In this dissertation, the relationship between PA and health service utilization among older adults and the role of PA in reducing health services utilization in this population is examined via two studies. **Study 1:** The purpose of Study 1 was to examine relationships between LTPA and health services utilization in a nationally representative sample of community-dwelling adults aged 50 years and older. **Methods:** This study involved a secondary analysis of data from the Cycle 3.1 of the Canadian Community Health Survey. The analysis was restricted to individuals aged 50 years and older, resulting in an unweighted sample of 56,652 adults (48%M; 52%F; mean age 63.5±10.2 years), stratified *a priori* into three age groups (50 – 64 years, 65 – 79 years, 80 years and older). Self-reported use of general physician (GP) services, specialist physician services and hospital services for the 12-month period prior to the survey were the outcomes of interest. The main independent variable of interest was self-reported LTPA for a 3-month period prior to the survey. A comprehensive set of predisposing, enabling, and health need factors associated with health services utilization were included as control variables in all analyses. Separate multiple logistic and negative binomial regression models were used to assess the association between LTPA and each dichotomous and count-based dependent variable, respectively. Bootstrap re-sampling procedures were applied in all regression analyses. **Results** In the 50-64 year age group, active individuals were 27% less likely to report any contact with a GP (OR=0.73; p<.001) and had 8% fewer GP consultations (IRR=0.92; p<.01) than their inactive counterparts. Among 65 to 79 year olds, active respondents were 18% less likely than their inactive counterparts to have had an

overnight hospitalization in the previous 12 months (OR=0.82, $p<.05$). Across all age groups, higher levels of non-leisure physical activity was associated with lower health services utilization.

Study 2: The purpose of Study 2 was to investigate the effects of a randomized community-based PA intervention (50+ *in motion*) on participants' health service utilization and healthcare costs over a 5-year period. **Methods:** 50+ *in motion* was a randomized clinical trial comparing the effectiveness of a class-based (CB) and home-based (HB) exercise program for older adults with select chronic health conditions (hypertension, dyslipidemia, type 2 diabetes mellitus, osteoarthritis, overweight or obesity). Of the 172 participants randomized, 59 CB and 69 HB participants granted access to their administrative health data. Data pertaining to GP and specialist physician services utilization and costs as well as hospital services utilization and costs were obtained for all consenting participants from the Saskatchewan Ministry of Health for the year prior to enrolment in the 50+ *in motion* study through to 48-months post-randomization, for a total of 5-years of data. Independent variables including demographic characteristics, physical activity, sedentary behaviour, cardiovascular endurance, functional fitness, body composition, blood pressure, and self-reported physical and mental health status were collected directly from participants prior to randomization and then annually for 4 years. Longitudinal effects of the 50+ *in motion* intervention on health services utilization and healthcare costs were assessed using the generalized estimating equation (GEE) approach with covariates selected for inclusion based on methods of purposeful selection. **Results:** There were no significant differences in health services utilization or health care costs between the CB and HB interventions until the final year of the study when the HB group had 60% more GP visits than the CB group and were 89% less likely than the CB group to be frequent users of specialist services. There were no significant differences between the randomization groups in healthcare costs. Measures of functional fitness emphasizing lower body strength, endurance and power were more consistently associated with lower health services utilization than CV endurance, body composition or physical activity. Sedentary behavior was associated with higher hospital costs, independent of physical activity, functional fitness and health status.

Overall Conclusion: Taken together, the two studies in this thesis address a significant gap in the Canadian literature and provide novel insights into the relationships between PA, health and health services utilization in older adults. While further research is needed to improve our understanding of the relationships between physical activity and sedentary behaviour, physical fitness, and health services utilization, the findings presented in this thesis suggest reducing sedentary behaviour and improving functional fitness in older adults may be as important as physical activity, if not more so, in terms of potential impact on health services utilization and health care costs. For health care professionals and policymakers at all levels, the findings highlight the advantages of a multi-pronged, interdisciplinary approach to the development of public health initiatives and interventions focused on increasing PA participation and functional fitness among older adults.

ACKNOWLEDGEMENTS

Throughout this endeavour, I have been very fortunate to be surrounded by an amazing group of mentors, colleagues, friends and family – without their guidance and support, this dissertation would not have been possible. First, I would like to thank my advisor, Dr. Karen Chad, for her tireless support and mentorship throughout the past decade. Karen, I have learned so much from you about many aspects of life, not just academia and I cannot thank you enough for your patience, understanding, compassion and unfailing support.

Many thanks as well to my committee members Dr. Liz Harrison, Dr. Bruce Reeder, and Dr. Nazmi Sari, for their individual and collective support and encouragement throughout this journey. It has been a privilege to work with each of you on this and other projects and your contributions to this research are greatly appreciated. I would also like to acknowledge the valuable contributions of the other members of the CIHR-CAHR Saskatoon *in motion* Older Adult Steering Committee – Dr. Nigel Ashworth, Dr. Suzanne Sheppard, Ms. Jodie Beattie-Flath, and Dr. Brenda Bruner – to this work.

I am indebted to Dr. Punam Pahwa and Dr. Joshua Lawson for so generously sharing their time and statistical expertise with me. You have been both mentors and friends, so thank you. I would also like to recognize Mr. Jesse McCrosky (Saskatchewan Research Data Centre), Dr. Mary Rose Stang (Saskatchewan Health Epidemiology & Research Unit), and Dr. Anne Pausjenssen, all of whom were instrumental to the completion of this research project. Jesse and Mary Rose, thank you for your assistance in navigating Statistics Canada's and Saskatchewan Health's respective processes for accessing data. Anne, thank you for your willingness to share both your time and expertise in wading through the countless pages of diagnostic and procedure coding manuals to help prepare the Saskatchewan Health data request. To all of you, your advice and expertise were invaluable to the completion of this project.

In addition, I would like to acknowledge the Saskatchewan Population Health and Evaluation Research Unit, the Western Regional Training Centre for Health Services Research and the Canadian Institutes for Health Research/Community Alliance for Health Research Grant 'Saskatoon *in motion*: Building Community Capacity Through Physical Activity and Health Promotion Research' for scholarship support I received while completing my doctoral studies.

To the wonderful group of amazing people I am lucky enough to call my friends– I would not have been able to get through the last few years without each and every one of you. In our friendships I found a soft place to land when I needed it the most and for that, I will be eternally grateful.

Lastly, to the participants of the 50+ *in motion* study – thank you for your commitment to this project and for your sincere desire to give back to your community. You were the cornerstone of this research – for without you, none of this would have been possible.

DEDICATION

Completing a Ph.D. is just one of many goals that I have been able to pursue because of the ongoing love and support of my family. To my parents and my brother, Craig – your encouragement and support gave me the confidence to begin this journey and kept me going through all of its ups and downs. To my sister-in-law, Jennifer, your happy and positive outlook on life is irresistible and brightened many of my hardest days. To my beloved nephews, Hudson and Griffin, you bring such joy and adventure to every day and your curiosity and excitement about the world around you is truly inspiring. There are not enough words to tell you how much you all mean to me.

This thesis is dedicated to my parents, Grant and Deanna.

You taught us what was important in life and gave us the best examples of patience, kindness, hard work, and integrity in the way you lived your lives every day. While I wish you were here to celebrate the completion of this journey that you made possible, I know that you are with me, always.

i carry your heart with me, i carry it in my heart
– e.e. cummings

TABLE OF CONTENTS

LIST OF TABLES

Appendices

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADL	Activities of daily living
AF	Atrial fibrillation
ANOVA	Analysis of variance
ARA	American Rheumatology Association
BMHSU	Behavioral Model of Health Services Utilization
BMI	Body mass index
CAM	Complementary and alternative medicine
CB	Class-based
CHMS	Canadian Health Measures Survey
CCHS	Canadian Community Health Survey
CCI	Canadian Classification of Health Interventions
CCP	Canadian Classification of Diagnostic, Therapeutic and Surgical Procedures
CEP	Certified Exercise Physiologist
CHD	Coronary heart disease
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
CSEP	Canadian Society for Exercise Physiology
CSST	Chair Sit to Stand Test
CV	Cardiovascular
CVD	Cardiovascular disease
DARC	Data Access Review Committee
DBP	Diastolic blood pressure
DPG	Day Procedure Group
ER	Emergency room
GEE	Generalized estimating equation
GH	Growth hormone
GP	General Practitioner
HB	Home-based
HCC	Healthcare costs
HMO	Health management organization
HSN	Health services number
HSU	Health services utilization
ICD	International Statistical Classification of Diseases and Related Health Problems
IGF-1	Insulin-like growth factor - 1
IHD	Ischemic heart disease

IRR	Incident rate ratio
KKD	Kilocalories per kilogram per day
LTPA	Leisure-time physical activity
LV	Left ventricular
MAP	Mean arterial pressure
MCS-12	SF-12 Mental Component Summary Score
MET	Metabolic equivalent
MLTPAQ	Minnesota Leisure-time Physical Activity Questionnaire
MVPA	Moderate to vigorous physical activity
NB	Negative binomial
NCD	Non-communicable disease
OA	Osteoarthritis
OR	Odds ratio
PA	Physical activity
PAI	Physical activity index
PASE	Physical Activity Scale for the Elderly
PCS-12	SF-12 Physical Component Summary Score
PPT	Physical Performance Test
RDC	Research Data Centre
RIW	Resource intensity weight
RPE	Rating of perceived exertion
SBP	Systolic blood pressure
SD	Standard deviation
SE	Standard error
SF-12	Medical Outcomes Short Form-12
SF-36	Medical Outcomes Short Form-36
SK HEALTH	Saskatchewan Ministry of Health
SSHRC	Social Sciences and Humanities Research Council
T1D	Type 1 diabetes
T2D	Type 2 diabetes
TSCT	Timed Stair Climb Test
WC	Waist circumference
6MWT	6-Minute Walk Test

LIST OF APPENDICES

DISCLOSURES

This research was funded through a Community Alliance for Health Research (CAHR) grant (CIHR FRN43282) from the Canadian Institutes for Health Research (CIHR). This thesis is based, in part, on data provided by Statistics Canada (Study 1) and the Saskatchewan Ministry of Health (Study 2 – with the written consent of the beneficiary). The interpretation and conclusions contained herein do not necessarily represent those of Statistics Canada, the Government of Saskatchewan or Saskatchewan Ministry of Health.

A portion of this thesis has been previously published in:
Reeder BA, Chad KE, Harrison EL, Ashworth NL, Sheppard MS, Fisher KL, Bruner BG, Quinn B, Pahwa P, Hossain MA. Saskatoon in motion: Class- vs. home-based physical activity promotion in older adults with chronic disease. *Journal of Physical Activity and Health* 2008; 5(1):74-87.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND AND RATIONALE FOR THESIS

Canada's population is aging such that by 2036, the number of seniors is projected to reach approximately 10 million, accounting for between 23% and 25% of the total population.[1] This demographic shift, which has been underway globally for almost 50 years, is driven by several factors, the primary ones being the nation's long-standing below-replacement-level fertility rate and an increasing life expectancy.[2]

The proportion of people aged 60 years and older is now the fastest growing segment of the population. Between 2006 and 2011, the number of people 60 to 64 years of age increased by 29% while the number of centenarians increased 25.7%.[2] Given that the average life expectancy at 65 years of age is now 21.5 years for women and 18.3 years for men; individuals reaching this age in relatively good health potentially have one quarter or more of their life remaining.[3] The unprecedented growth of the older adult population is expected to have significant economic and societal implications both globally and for Canadians.[4-6]

Aging is associated with an increased incidence and prevalence of most chronic conditions along with increased impairment and disability associated with functional decline. Recent estimates suggest that by age 65, 77% of men and 85% of women will have at least one chronic condition, the most prevalent being cardiovascular disease, cancer, respiratory disease, arthritis and diabetes, and 25% will have four chronic conditions or more.[7,8] With substantial growth expected in this segment of the population, it is likely that a significant proportion of the population will require ongoing, long term medical care to manage their chronic conditions.

However, the Canadian healthcare system was not designed to provide this type of care. Rather, it was originally implemented to address short term, acute, and emergent healthcare needs.[9] Thus, there is great concern that the increasing chronic care needs of older adults will place considerable strain on the healthcare system, both in terms of its capacity to meet an increasing demand for services and its ability to sustain the current level of service provision in the face of increasing costs.[5,10]

Many of the chronic conditions associated with aging share a constellation of lifestyle-related risk factors, one of which is physical inactivity. The importance of physical activity in reducing chronic disease and maintaining good health and functional independence has been well documented.[11-15] The health benefits of exercise, including enhanced cardiovascular functioning, improved glucose tolerance, and obesity reduction, are well known.[4,12,15,16] Improvements in conditions such as osteoporosis, sarcopenia, and certain forms of cancer[11,12,15,17], positive changes in mental health, particularly related to depression and stress management, and improvements in cognitive ability, quality of life, and well-being[12,15] have also been linked to increased physical activity levels.

Given the strong associations between physical activity and the aforementioned chronic conditions, the potential economic and social burden presented by a physically inactive population is thought to be substantial. Globally, it is estimated that 6–10% of all deaths from non-communicable diseases (NCD) can be attributed to physical inactivity, including approximately 30% of cases of ischemic heart disease and approximately 15% of cases of T2DM and breast, colon and rectal cancers worldwide.[18] In Canada, it has been estimated that just a 10% reduction in physical inactivity would result in a decrease in direct health care expenditures of approximately $150 million per year.[19,20] Although the importance of being physically active is widely acknowledged among the Canadian population, levels of physical activity remain low, particularly among older adults.[21] Despite targeted strategies to increase physical activity in this segment of the population, fewer than 10% of older adults meet current physical activity recommendations.[21]

There has been a growing interest among policymakers in the potential role of physical activity as a strategy to mitigate the challenges associated with an aging population, specifically the potential pressures on the health care system presented by an increasing need and demand for long term management of chronic health conditions.[22-24] However, there has been very little research in the area of physical activity and health services utilization, particularly in Canada.[25-28] A recent study examining the association between physical activity and health service utilization found physical inactivity to be associated with 5.5% more GP visits, 13% more specialist visits, and 38% more nights in hospital in a nationally representative sample of Canadians 12 years of age and older.[26] These results are consistent with studies of representative samples of American and European general populations which have found differences in health service utilization between active and inactive ranging from 20% to 36% for inpatient services and hospital days and 6% to 28% for outpatient services.[29-31] These findings suggest that assumptions regarding physical activity as an effective strategy to reduce health services utilization are well founded; however, of the few studies in this area, the majority have been carried out in the general population. Significant gaps remain in our understanding of the relationship between physical activity and health services utilization as it pertains to the most frequent users of health services, that being the older adult population.[32] A recently published review of literature related to physical activity and its implications for health services utilization in older adults highlights the need for additional observational and intervention studies, such as those undertaken in this thesis, to provide more robust estimates of the effect of physical activity on health service utilization.[27]

1.2 OBJECTIVES, RESEARCH QUESTIONS AND HYPOTHESES

The overall purpose of this thesis was to examine the relationship between physical activity and health service utilization among older adults and the role of physical activity in reducing health services utilization in this population. Two studies were needed to realize this objective. The first study explored the independent association of leisure time physical activity with health services utilization in a nationally representative sample of Canadians 50 years of age and older. The second study was a longitudinal examination of the effects of a randomized, community-based physical activity intervention targeting older adults with chronic conditions on health service utilization over a 5-year period. Together, these studies provide novel insights into the relationships between physical activity, health and health services utilization in older adults which may be used by policymakers at all levels to inform their chronic disease management strategies. The specific objectives and hypotheses for each study are described below.

1.2.1 Study 1: Physical inactivity and health services utilization among older Canadians: Findings from the Canadian Community Health Survey

This study involved a secondary analysis of data from Cycle 3.1 of the Canadian Community Health Survey (CCHS). The objective of this study was to examine the independent association of leisure time physical activity with health services utilization in Canadians 50 years of age and older.

Research Question:

1. Is leisure time physical activity (LTPA) associated with lower health services utilization (HSU) among Canadians aged 50 years and older?

Hypothesis:

1. LTPA is independently associated with HSU such that physically active older adults would use fewer health services (general physician services, specialist physician services and hospital services) than their inactive counterparts, after adjusting for other known determinants of HSU.

1.2.2 Study 2: The effects of a randomized, community-based physical activity intervention on health service utilization in community-dwelling older adults

This study examined the effects of a randomized community-based physical activity intervention[33] on HSU and associated health care costs (HCC) over a 5-year period in a group of sedentary older adults with selected chronic health conditions.

Research Questions:

1. Did HSU and HCC differ between intervention groups (class-based vs. home-based physical activity) over the 5-year study period?
2. Did HSU and HCC vary as a function of physical activity level, cardiorespiratory endurance, and/or physical function over the 5-year study period?

Hypotheses:

1. No specific hypothesis was formulated for the first research question because of the equivocal nature of the findings reported in the literature comparing the efficacy of class-based and home-based PA interventions.[28,33,34]
2. HSU and HCC will be lower among participants who improved their level of physical activity, cardiorespiratory endurance and physical function and maintained those improvements over the study period.

1.3 THESIS STRUCTURE

As outlined above, this dissertation involved two separate but related studies which are presented as Chapters 4 and 5. In order to provide the necessary background to these studies, a general review of the literature relating to the following areas: 1) aging and health; 2) physical activity; aging and health; and 3) health services utilization is provided in Chapter 2. Chapter 3 includes an overview of the statistical methodology common to both studies and methodological information pertaining to the use of Saskatchewan Health administrative health databases. The final chapter includes a general discussion of the findings including the study limitations and directions for future research. A complete list of references cited follows each chapter and appendices are included at the end of the thesis document.

1.4 LITERATURE CITED

1. Statistics Canada. *Population projections for Canada, provinces and territories.* Demography Division, ed. Ottawa, ON: Ministry of Industry, Government of Canada; 2010.

2. Statistics Canada. 2011 Census: Age and sex. *The Daily.* Tuesday, May 29, 2012.

3. Organization for Economic Co-operation and Development. *Health at a Glance 2011: OECD Indicators.* Paris France: OECD Publishing;2011.

4. United Nations Department of Economic and Social Affairs Population Division. World population ageing 1950-2050. New York: United Nations 2002.

5. Canadian Institute for Health Information. *Health care in Canada, 2011. A focus on seniors and aging.* Ottawa, ON;2011.

6. Bloom DE, Canning D, Fink G. *Implications of population aging for economic growth.* In: *Program on the Global Demography of Aging: Working Paper Series*. Cambridge, MA: Harvard University;2011.

7. Gilmour H, Park J. Dependancy, chronic conditions and pain in seniors. *Health Reports.* 2006;16(Suppl):21-31.

8. Ramage-Morin PL, Shields M, Martel L. Health-promoting factors and good health among Canadians in mid- to late life. *Health Reports.* 2010;21(3):45-53.

9. Taylor MG. *Health Insurance and Canadian Public Policy: The Seven Decisions That Created the Health Insurance System and Their Outcomes.* Montreal & Kingston: McGill-Queen's University Press; 2009.

10. Vegda K, Nie J, Wang L, Tracy CS, Moineddin R, Upshur R. Trends in health services utilization, medication use, and health conditions among older adults: a 2-year retrospective chart review in a primary care practice. *BMC Health Services Research.* 2009;9(1):217.

11. United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council of Physical Fitness and Sport. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: United States Department of Health and Human Services; 1996.

12. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: The evidence. *Canadian Medical Association Journal.* 2006;174(6):801-809.

13. Paterson DH, Jones GR, Rice CL. Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Canadian Journal of Public Health.* 2007;98 (Suppl 2):S69-S108.

14. Paterson D, Warburton D. Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):38.

15. Warburton D, Charlesworth S, Ivey A, Nettlefold L, Bredin S. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):39.

16. Katzmarzyk PT, Lear SA. Physical activity for obese individuals: a systematic review of effects on chronic disease risk factors. *Obesity Reviews.* 2012;13(2):95-105.

17. Melzer K, Kayser B, Pichard C. Physical activity:The health benefits outweigh the risks. *Current Opinion in Clinical Nutrition and Metabolic Care.* 2004;7:641-647.

18. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair S, Katzmarzyk P. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet.* 2012;380:219-229.

19. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

20. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: An update. *Canadian Journal of Applied Physiology.* 2004;29(1):90-115.

21. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports,.* 2011;22(1):7-14.

22. Lankenau B, Solari A, Pratt M. International physical activity policy development: A commentary. *Public Health Reports.* 2004;119(3):352-355.

23. Craig CL. Evolution and devolution of national physical activity policy in Canada. *Journal of Physical Activity and Health.* 2011;8:1044-1056.

24. Kohl HW, 3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, Kahlmeier S. Physical Activity 5: The pandemic of physical inactivity: global action for public health. *The Lancet.* 2012;380(9838):294-305.

25. Herman KM, Ardern CI, Mason C, Brien SE, Katzmarzyk PT. Trends in physical activity research in Canada. *Applied Physiology, Nutrition, and Metabolism.* 2007;32(3):400-408.

26. Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

27. Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

28. Ashworth NL, Chad KE, Harrison EL, Reeder BA, Marshall SC. Home versus center-based physcial activity programs in older adults. *Cochrane Database of Systematic Reviews.* 2005 (Updated 2009);Issue 1.

29. Keeler EB, Manning WG, Newhouse JP, Sloss EM, Wasserman J. The external costs of a sedentary lifestyle. *American Journal of Public Health.* 1989;79(8):975-981.

30. Manning WG, Keeler EB, Newhouse JP, Sloss EM, Wasserman J. *The Costs of Poor Health Habits.* Cambridge, MA: Harvard University Press; 1991.

31. Haapanen-Niemi N, Miilunpalo S, Vuori I, Pasanen M, Oja P. The impact of smoking, alcohol consumption, and physical activity on use of hospital services. *American Journal of Public Health.* 1999;89(5):691-698.

32. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4):392-410.

33. Reeder BA, Chad KE, Harrison EL, Ashworth NL, Sheppard MS, Fisher KL, Bruner BG, Quinn BG, Pahwa P, Hossain MA. Saskatoon *in motion*: Class- versus home-based exercise intervention for older adults with chronic health conditions. *Journal of Physical Activity & Health.* 2008;5(1):74-87.

34. Foster C, Hillsdon M, Thorogood M, Kaur A, WedatilakeT. Interventions for promoting physical activity. *Cochrane Database of Systematic Reviews.* 2005 (updated 2013);Issue 1.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 AGING AND HEALTH

Aging is a multidimensional and complex process that begins the moment we are born. Prior to maturation, aging is characterized as growth and is associated with systemic increases in functional capacity, including cardiovascular and respiratory performance, muscular strength and endurance, which typically reach their peak in early adulthood.[1] Once in adulthood, aging is described as the general, progressive, natural decline in physiological function affecting most of the body's organs and systems. The natural processes of aging are influenced by several factors including genetic and biological characteristics, socioeconomic influences, environmental stressors and lifestyle behaviors. While aging is a universal experience; chronological age is often a poor predictor of changes associated with aging.[1-3] The life course perspective of aging posits that health and activity in older age reflect the circumstances and actions of an individual across their entire lifespan.[4] This conceptual framework underpins the World Health Organization's (WHO) Programme on Ageing and Health and is shown below in Figure 2.1.[5]

Poor health, disability and dependency among older adults are largely a consequence of chronic diseases or conditions and injuries resulting from falls.[6,7] Although many of these conditions are associated with age and/or heredity, most are also associated with several key modifiable risk factors: tobacco use, poor diet and physical inactivity. It is the influence of these and other modifiable factors that have the most pronounced influence over the slope of the natural decline in functional capacity.[5]

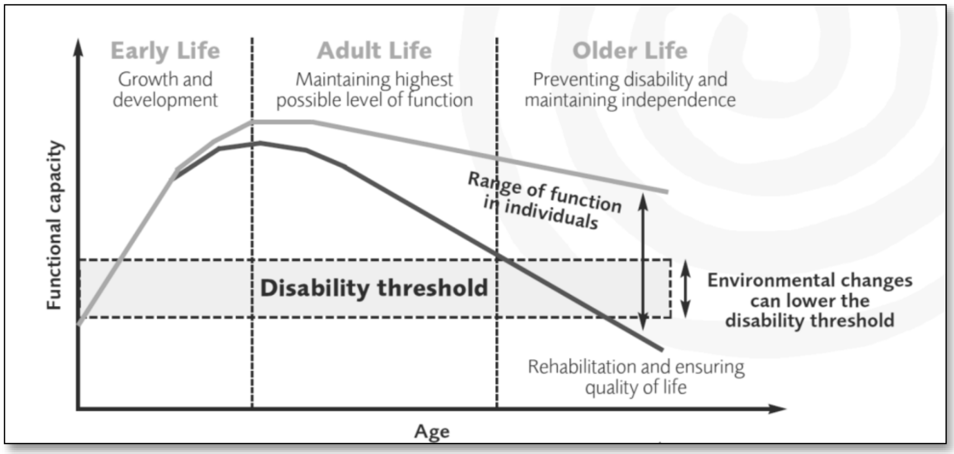


Figure 2.1 Aging and functional capacity across the lifespan (Adapted from WHO, 2000)[5]

As a result, the "disability threshold" depicted in Figure 2.1 cannot be precisely defined, as it will differ significantly depending upon an individual's particular life course and circumstances.[4] For example, a person who experiences significant declines in physical function but is living in a supportive environment may continue to live independently while another, at a similar level of functional capacity but in a less supportive environment, may experience a loss of independence.[4]

Health promotion initiatives for older adults typically include strategies for maintaining or increasing positive lifestyle behaviours with goals such as slowing the decline in functional capacity and/or the maintenance of independence and quality of life as one grows older.[6-8]

2.1.1 Healthy Aging

What does it mean to age successfully? There is little consensus in the literature on the optimal definition of healthy aging.[9,10] The systematic study of healthy aging, also known as "successful aging", or "productive aging", is a relatively recent development in the gerontological literature.[9,10] The prevailing model, advanced by Rowe and Kahn (1987), posits that the rate of functional decline in older adults is not solely related to age but also to extrinsic factors such as environment, lifestyle and psychosocial influences.[11] This model distinguishes usual aging, in which these extrinsic factors heighten the effects of age-associated functional declines, from successful aging, in which the effects of extrinsic influences are neutral or even positive.[11,12] Healthy aging, therefore, can be characterized as including a low probability of disease-related disability, a high level of functional ability, and active engagement in life.[11,13,14] Other definitions of healthy aging involve the degree to which older individuals adapt to age-related changes[15], view themselves as aging successfully[16], or avoid morbidity up until death.[17] Canada's Chief Public Health Officer (2010) defines healthy aging as "an ongoing process of optimizing opportunities to maintain and enhance physical, social and mental health, as well as independence and quality of life over the lifecourse".[7] Although there is no one definition of positive or healthy aging, at its base is the idea of maximizing the quality of life and well-being of older adults. The characteristics and conditions associated with healthy, positive aging have been described as follows:[18]

- Productive, active participation in all aspects of economic, social and community life;
- Self-reliance/self-determination;
- Recognition as an actively contributing member of society;
- A positive outlook on self and future;
- Good physical and mental health and ability to function;
- Mutually supportive social relationships and contacts;
- Financial security;
- Safe and supportive environment/community to live and work;
- Availability of adequate services and support (National Seniors Council, 2010).

The determinants of healthy aging are reflective of the broader determinants of health (Figure 2.2). Many chronic diseases and conditions are associated with age and heredity;

however, health outcomes are also strongly influenced by social, economic and environmental factors, with their cumulative impact becoming more apparent as people age.[7,19-21]

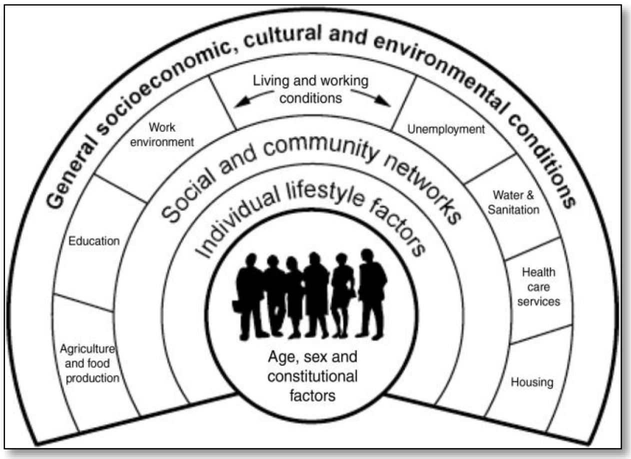


Figure 2.2 Individual, social and environmental determinants of health and well-being (Adapted from Dahlgren & Whitehead, 1991)[19,20]

While aging is often accompanied with increasing health problems, some people remain healthy as they age. Martel et al (2005)[21] examined the factors affecting one's chances of remaining in good health, demonstrating that they differed between middle aged (aged 45-64 years) and senior (aged 65 years and older) adults. Socio-economic factors such as education and income were significant while lifestyle related factors, including smoking and physical inactivity were not significantly related to health aging in middle aged adults. For seniors, however, smoking and physical inactivity were significantly associated with an increased risk of losing their health, supporting the hypothesis that the effects of healthy lifestyle behaviors are cumulative over the life course.[21]

2.1.2 The Health of Canada's Aging Population

For the most part, older Canadians enjoy good health, with approximately three-quarters of Canadian seniors rating their health as good, very good or excellent.[22,23] Nonetheless, more than 80% of independent seniors live with one or more chronic conditions. Arthritis (>45%), hypertension (>40%), back problems (~25%), heart disease (~20%) and diabetes (~14%) are among the most commonly reported chronic conditions among older adults, with the prevalence of most increasing with age.[23] Cancer, heart disease, and stroke are the top three leading causes of death in seniors, accounting for two-thirds of all deaths in Canada.[24,25] Injuries related to falling are a considerable concern, with 63% of seniors reporting a fall-related injury in 2009-2010.[25] Falls account for more than half of all injuries and 20% of injury-related deaths among Canadians 65 years and older.[26] Among older adults aged 55 to 64 years, 39% reported a participation or activity limitation, which rose to over 50% in those aged 65 years and older.[25,27] As they age, seniors tend to develop health problems that cause them to increase their use of health services. The vast majority of seniors (approximately 90%) report visiting their physician at least once per year, with almost 45% reporting four or more visits.[28] On the other hand, fewer than 15% of Canadian older adults report consulting alternative health care providers such as chiropractors and massage therapists.[29]

Today, older Canadians are living longer and with fewer disabilities than previous generations. At the same time, the majority of seniors have at least one chronic disease or condition. Seniors with three or more chronic conditions use three times the health services and report twice the rate of visits to the doctor than seniors reporting only one condition.[30] Given that our health care system primarily focuses on cure rather than health promotion and disease prevention, redirecting attention to the latter will be necessary in order to enable older people maintain optimal health and quality of life and adequately manage future demand for healthcare.[31]

2.1.3 *The Aging Process*

The capacity of most physiological systems decline with age, some by more than 40% (e.g. cardiovascular, neuromuscular) over one's lifespan.[32] This decline in function is thought to reflect the lifetime accumulation of molecular and cellular damage caused and regulated through a complex web of mechanisms and processes that are influenced by social, environment and behavioural factors (Figure 2.3).[3,33,34]

Several mechanisms have been identified as key drivers of the aging process, including protein damage, DNA damage, mitochondrial dysfunction, inflammation and oxidative stress.[3] These pathways are not mutually exclusive, and different physiological or biological events may drive different age-related processes.[3] Genetic effects are expressed primarily through DNA maintenance and repair functions, which regulate the rate at which cellular defects accumulate. Cellular defects often cause chronic low-grade inflammation, which itself can exacerbate existing damage. Therefore, inflammatory and anti-inflammatory factors play an important role in shaping the outcomes of the aging process.[3] Finally, environmental and behavioural factors (including nutrition and lifestyle) can either increase or help to decrease the accumulation of molecular damage.[33]

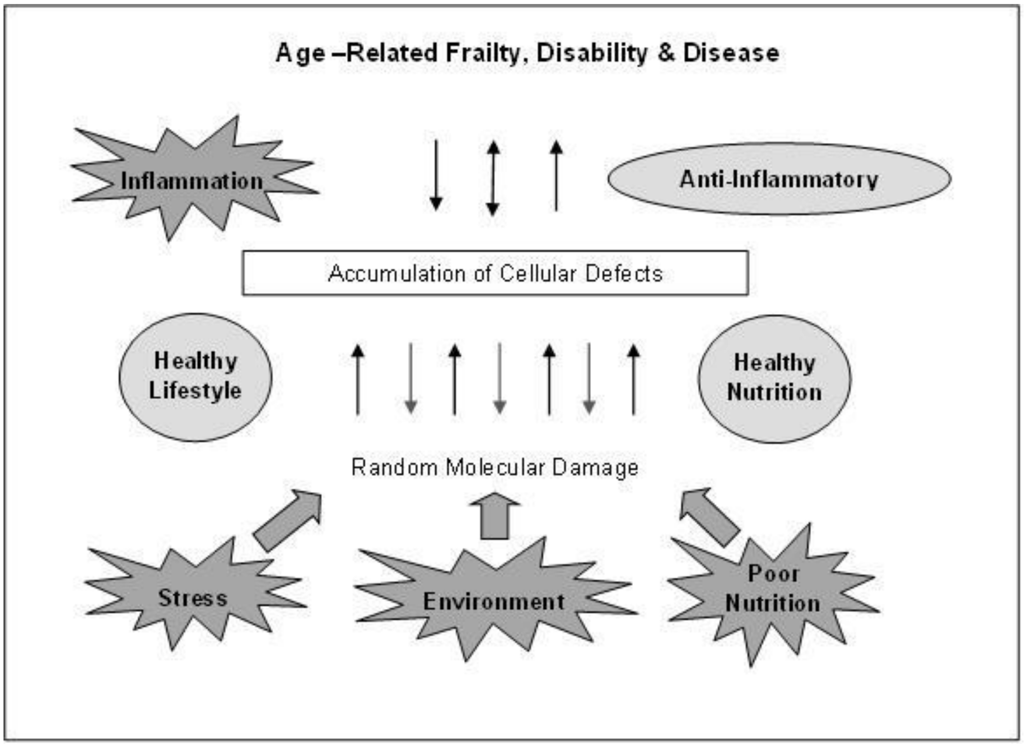


Figure 2.3 The aging process (Adapted from: Kirkwood, 2005)[33]

Depending on the rate and degree of deterioration, the cumulative decline in multiple physiological systems can potentially lead to a state of frailty. Frailty is a geriatric syndrome characterized by decreased reserve and progressively increasing vulnerability to stressors, with significant implications for independence and quality of life.[32-36] Distinct from comorbidity or disability, frailty is a complex interplay of a person's strengths and deficits as a result of the combination of factors such as age, gender, lifestyle, socioeconomic background, comorbidities and affective, cognitive or sensory impairments.[37]

2.1.4 Aging, Physiological Function and Chronic Disease

Most chronic conditions associated with aging are the result in the diminished ability of cells and tissues in the body to maintain homeostasis, particularly when placed under stress. Hence, it can be difficult to disentangle normal process of aging from pathological disease processes. Advancing age is a primary risk factor for a number of chronic conditions, including but not limited to: hypertension, cardiovascular disease, sarcopenia, osteoarthritis, osteoporosis, metabolic syndrome and type 2 diabetes, and cancer.[38-40] In the following sections, aging-related changes in physiological function and their role in the development of the aforementioned conditions are outlined.

2.1.4.1 Cardiovascular Health and Disease

Overall cardiovascular (CV) performance is determined by the integrated function of the arterial and cardiac systems.[41] Progressive changes in CV structure and function occur as a normal part of aging, even in apparently healthy individuals. Age-induced CV changes are often adaptations resulting from changes in other systems in the body. For instance, the overall function of the CV system is significantly affected by altered functioning of the autonomic nervous system.[42] Furthermore, certain age-related CV changes differ between men and women, such as alterations in cardiac contractile proteins brought about by reductions in circulating testosterone levels.[42-44] Important changes associated with an aging CV system include increased arterial stiffness, impaired endothelial function, cardiac hypertrophy, altered left ventricular (LV) diastolic function, and diminished LV systolic reserve capacity (Figure 2.4).[41,42,45]

Age-related vascular changes

Arteriosclerosis – the thickening and stiffening of the large arteries – is caused by collagen and calcium deposition and the loss of elastic fibers in the arterial walls.[44] Although age is the most important contributing factor to arteriosclerosis, the degree to which vascular changes occur can be accelerated by other clinical factors, including hypertension, diabetes mellitus, dyslipidemia and vascular inflammation.[46] It is thought that these contributing factors act through a common pathway of increased oxidative stress and vascular inflammation, leading to adverse vascular remodeling and accelerated arterial ageing.[46]

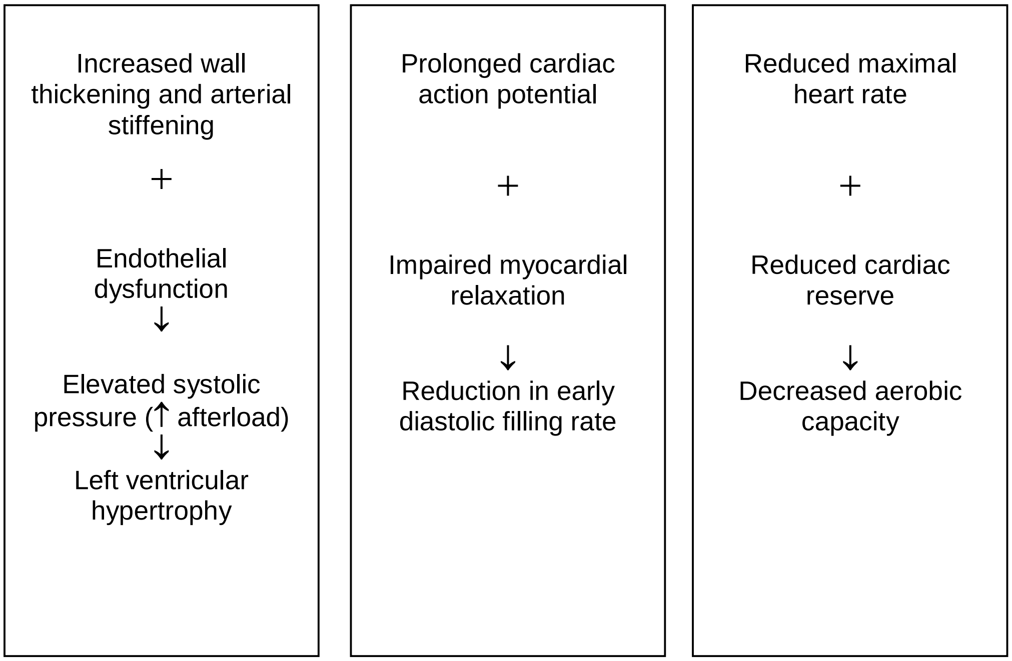


Figure 2.4 Age-related changes in the cardiovascular system.
Adapted from Webb & Inscho, 2009.[42]

The functional decline in arteriosclerosis is characterized by endothelial dysfunction with significant decreases in nitric oxide and β_2-receptor dependent vasodilation, both of which promote vasoconstriction.[42,46] The loss of arterial distensibility resulting from endothelial dysfunction will lead to increases in systolic blood pressure and pulse pressure, which in turn leads to further reductions in arterial compliance.[42,46] In addition to hypertension, arteriosclerosis is implicated in many other CV conditions, including hypercholesterolemia and coronary and peripheral atherosclerosis.[44] These intermediate conditions may, over time, lead to more complex renal and cerebrovascular issues.

Age-related changes in cardiac structure & function

Increased left ventricular (LV) wall thickness, altered diastolic filling, impaired LV ejection and reduced HR reserve capacity are the most significant age-dependent changes in cardiac function occurring in healthy persons.[45,47] These changes do not necessarily result in clinical heart disease; however, they are likely contributing factors to the increased prevalence of left ventricular hypertrophy, chronic heart failure and atrial fibrillation seen with increasing age.[45,47]

Age-related increases in arterial stiffness and the resultant increase in systolic blood pressure leads to progressive increases in LV wall thickness, even in normotensive individuals.[42,47] Since the change in wall thickness is more pronounced at the interventricular septum than the free wall, the LV becomes less elliptical and more spherically shaped; the consequence of which is a decrease in contractile efficiency and reduced LV systolic reserve.[44]

Changes in diastolic function of the left ventricle are also evident across the lifespan. Early diastolic filling of the LV peaks during young adulthood and progressively slows with age where at 80 years of age, the rate is approximately 50% of its peak value.[42] Adequate ventricular filling is maintained through a compensatory increase in atrial contraction which results in augmented LV filling in late diastole thereby sustaining stroke volume and sufficient ejection fraction.[41,42] The delay in LV filling is likely the result of reduced LV compliance due to fibrotic changes to the myocardium and prolonged myocardial contraction resulting from the impairment of calcium accumulation by the sarcoplasmic reticulum.[44] The increased contribution of the atria to maintain adequate diastolic filling leads to hypertrophy which, over time, may lead to a reduction in cardiac function.[41]

Age-related changes in cardiovascular regulation

With aging, autonomic cardiovascular control at rest is relatively well maintained; however, age-related changes to sympathetic and parasympathetic tone may reduce the ability of the CV system to respond to acute physiological challenges.[48] Although aging is associated with sustained increases in resting sympathetic nerve activity, sensitivity of catecholamine receptors in the heart and blood vessels are reduced, resulting in diminished vasodilation, heart rate, and cardiac output responses.[48] These changes result in a decline of approximately 5 $ml \cdot kg^{-1} \cdot min^{-1}$ per decade in maximal aerobic capacity throughout adulthood.[45,49]

Less understood are changes related to parasympathetic tone and heart rate that are seen with increasing age.[41] Although resting heart rate does not dramatically change with age, the maximum heart rate achievable declines by approximately 30% between 20 and 85 years of age.[42,47] Heart rate variability (variation in the beat-to-beat interval) also declines with age; this is thought to reflect the autonomic dysregulation (specifically, diminished vagal tone) commonly found in older adults.[42] After the age of 60 years, there is also a marked decrease in the number of pacemaker cells of the sino-atrial node; by 75 years of age the number of cells is 90% less than the number found in a young adult.[45] In addition, cardiac fibrosis and hypertrophy associated with aging will result in the slower propagation of electric impulse throughout the heart.[41,45]

Cardiovascular Aging and Cardiovascular Disease

It is very difficult, if not impossible, to clearly distinguish components of normal cardiovascular aging from pathological disease processes. In fact, age-associated changes in CV structure and function are the foundation on which cardiovascular diseases (CVDs) develop.[42,45,50] The relationship between cardiovascular aging and the development of CVD is shown in Figure 2.5.

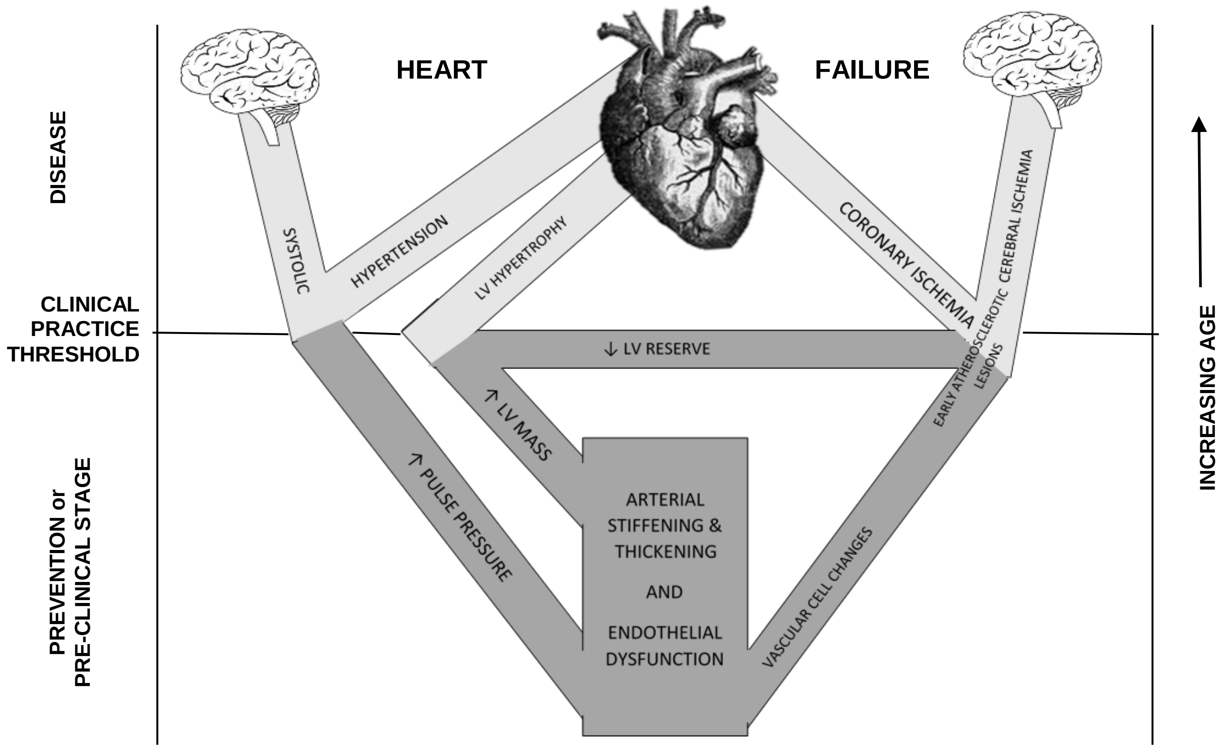


Figure 2.5 Relationship between cardiovascular aging and the development of cardiovascular disease (Adapted from Lakatta, 2002).[51]

Advanced age is an important independent risk factor in the development of several CVDs and risk conditions, including hypertension, ischemic heart disease (IHD), atrial fibrillation (AF), congestive heart failure and cerebrovascular disease (stroke).[42,50] Among those 65 years of age and older, CVD is a leading cause of death, resulting in 40% of all deaths in this age group.[41] Ischemic heart disease, in particular, is a significant cause of morbidity and mortality in older adults, with approximately 80% of all deaths from IHD occurring among those aged 65 years and older.[50] New pharmaceuticals and medical advances along with decreased rates of tobacco use have contributed to a decline in the mortality rate due to CVD of approximately 3% per year since 1960.[52] However, the costs associated with CVD, both in terms of economic costs and costs to quality of life, continue to be substantial. In 2005, costs related to healthcare (direct costs), lost productivity, disability and premature mortality (indirect costs) due to CVD were estimated to be $21 billion, making it the second-costliest disease in Canada.[52]

2.1.4.2 Musculoskeletal health and disease

Musculoskeletal health is a key determinant of functional capacity, independent living and quality of life.[40,53] The adequate functioning of the musculoskeletal system provides support and structure to the body, force and strength to move the body, and stability and flexibility in movement. Musculoskeletal aging is a complex process involving atrophy and loss of function in several different tissues – muscle, bone, tendon, ligaments, articular cartilage, and intervertebral disk – along with diminished neuromuscular integrity.[54] As with the cardiovascular system, it is often difficult to differentiate between the effects of aging, disuse and disease; however, age-related declines in these tissues can have profound effects on the functioning of the musculoskeletal system, contributing to several chronic conditions that are prevalent among older adults, including sarcopenia, osteoarthritis and osteoporosis.[55,56]

Among people aged 65 years and older, musculoskeletal conditions are the most common cause of chronic disability, a situation that is attributable both to the high prevalence of these conditions and the central role of the musculoskeletal system in physical function.[56] At an estimated cost of $22.3 billion annually, musculoskeletal diseases are the most costly condition in Canada. While the direct costs of musculoskeletal diseases and injury are significant, indirect costs associated with lost productivity, due to disability and/or premature death, account for 75% of the total economic burden.[57]

Sarcopenia

Skeletal muscle is fundamentally important to all aspects of daily life. Most people take for granted that they will have adequate strength to meet the challenges presented by the countless daily activities such as arising out of a chair, dressing, and bathing that we all encounter each and every day. When a person's ability to perform these activities is compromised, maintaining one's independence becomes very difficult, often necessitating a move to institutionalized care.[58] This, in turn, can have severe consequences, including social isolation and diminished quality of life.[59]

Sarcopenia, defined as the age-related decline of skeletal muscle mass, strength, and function, is thought to affect over 20% of Canadian older adults aged 60 to 70 years and close to 50% of those aged 75 years and older.[60,61] The loss of muscle mass associated with aging has been thought to be the primary contributor to the gradual decrease (10 – 15% per decade) in muscular strength typically seen with aging. However, longitudinal studies reveal that changes in muscle mass explain only 5% of changes in muscle strength, suggesting that other factors, in addition to muscle mass, contribute to muscle weakness.[62] These other age-dependent changes in muscle tissue are outlined in Table 2.1. While these sarcopenic changes begin around the age of 30 years, they are rarely functionally significant in healthy individuals until approximately 60 years of age.[32]

Table 2.1 Age-related anatomical changes in muscle.

1. Decreased muscle mass and cross-sectional area
2. Infiltration of fat and connective tissue
3. Decrease in type II fiber size with no change in type I fiber size
4. Decrease in type I and type II fiber number
5. Accumulation of internal nuclei, ring fibers, and ragged fibers
6. Disarrangement of myofilaments and Z-lines
7. Proliferation of the sarcoplasmic reticulum and t-tubular system
8. Accumulation of lipofuscin and nemaline rod structures
9. Decreased number and size of motor units.

Adapted from Kamel, 2003; Muscaritoli et al, 2010 [63,64]

The cause of sarcopenia is multi-factorial in nature, with age-related molecular and hormonal changes, neurological decline, increased inflammation, insulin resistance, chronic diseases, sub-optimal nutrition and declines in physical activity among the factors thought to contribute to the accelerated loss of muscle mass and function (See Figure 2.6).[60,61,65,66] Sarcopenia is a feature of several other chronic conditions including disease-related cachexia (e.g. in cancer or end-stage renal disease), osteoarthritis, and sarcopenic obesity.[65]

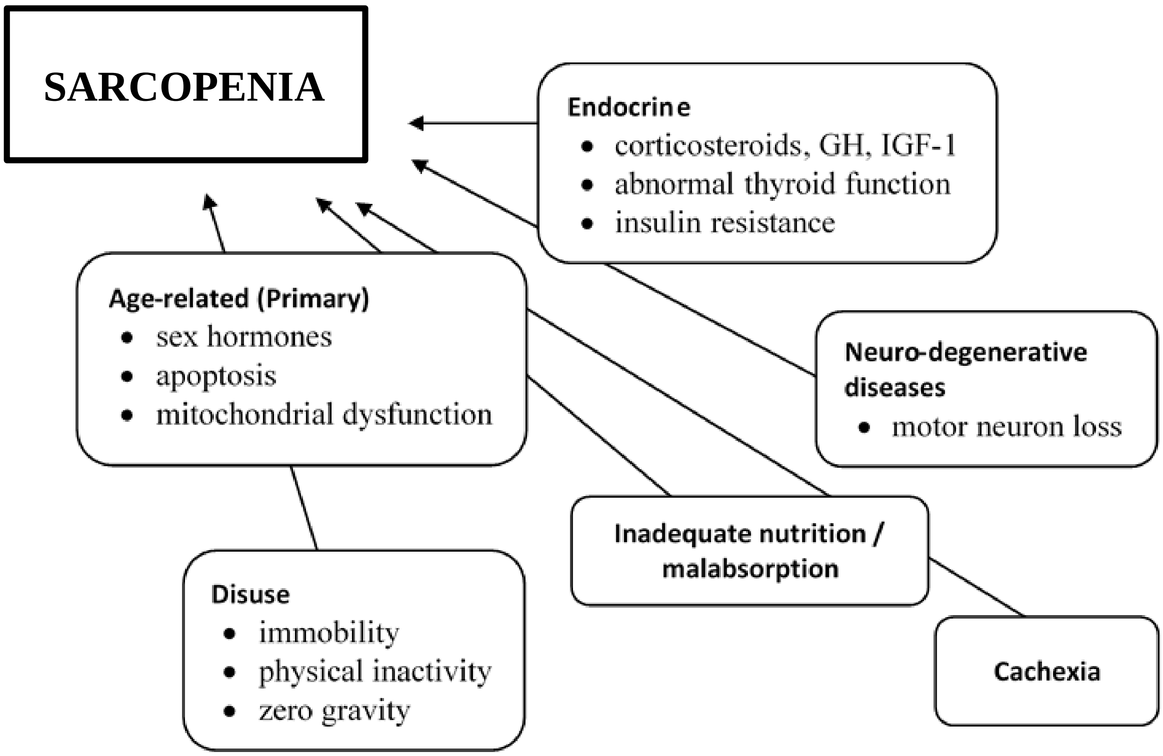


Figure 2.6 Mechanisms of sarcopenia. Adapted from Cruz-Jentoft et al, 2010.[65]

While there is currently no broadly accepted clinical definition of sarcopenia, a recently proposed system classifies and stages sarcopenia based upon the causal factors involved and the functional severity of the condition.[64,65] Primary sarcopenia is associated with aging itself, with no other evident cause identified while in secondary sarcopenia, one or more causes besides aging are present. Once classified, staging criteria are applied to describe the functional severity of the condition. These are outlined in Table 2.2.[65]

Table 2.2 Conceptual stages of sarcopenia

Stage	Muscle mass	Muscle strength		Performance
Pre-sarcopenia	↓	–		–
Sarcopenia	↓	↓	or	↓
Severe sarcopenia	↓	↓		↓

Adapted from: Cruz-Jentoft et al, 2010.[65]

The strength and functional declines associated with sarcopenia are serious and life-altering, with significant individual and societal impacts. Loss of strength and mobility deficits are associated with impaired balance, an increased risk of falls and bone fractures, significantly increased risk of disability, and frailty.[59,61,66] The risk of disability is 1.5 to 4.6 times higher in older persons with sarcopenia than in older persons with normal muscle.[67] In 2000, approximately $18.5 billion, or 1.5% of total direct healthcare costs in the United States were attributable to sarcopenia.[68]

Osteoarthritis

Osteoarthritis (OA) is the most common joint disorder in the world and is the most frequent source of pain and disability among older adults.[55,69,70] It is characterized by slow and progressive degradation and loss of articular cartilage in synovial joints with concomitant hypertrophy of the underlying bone and thickening of the joint capsule.[54,69,71] Structural changes to the joint are evident as early as the 3rd decade of life and most people have osteoarthritic changes in at least one joint by the age of 70 years.[71] Osteoarthritis is most commonly seen in the hip and knee joints along with the joints of the hands, feet and spine. Before 50 years of age, the prevalence of osteoarthritis is higher in men than in women across most joints while after the age of 50, women are more often affected with hand, foot, and knee osteoarthritis than men.[70,72]

While OA is considered a 'classic' age-related disorder, the literature currently conceptualizes the relationship between aging and OA be that of increased joint vulnerability and disease susceptibility, rather than one of a causal nature.[70] Genetic factors, anatomical structure, obesity and joint injuries are also contributing factors to the development of symptomatic OA.[55,70,71] The relationship between musculoskeletal aging and the development of OA is shown in Figure 2.7.

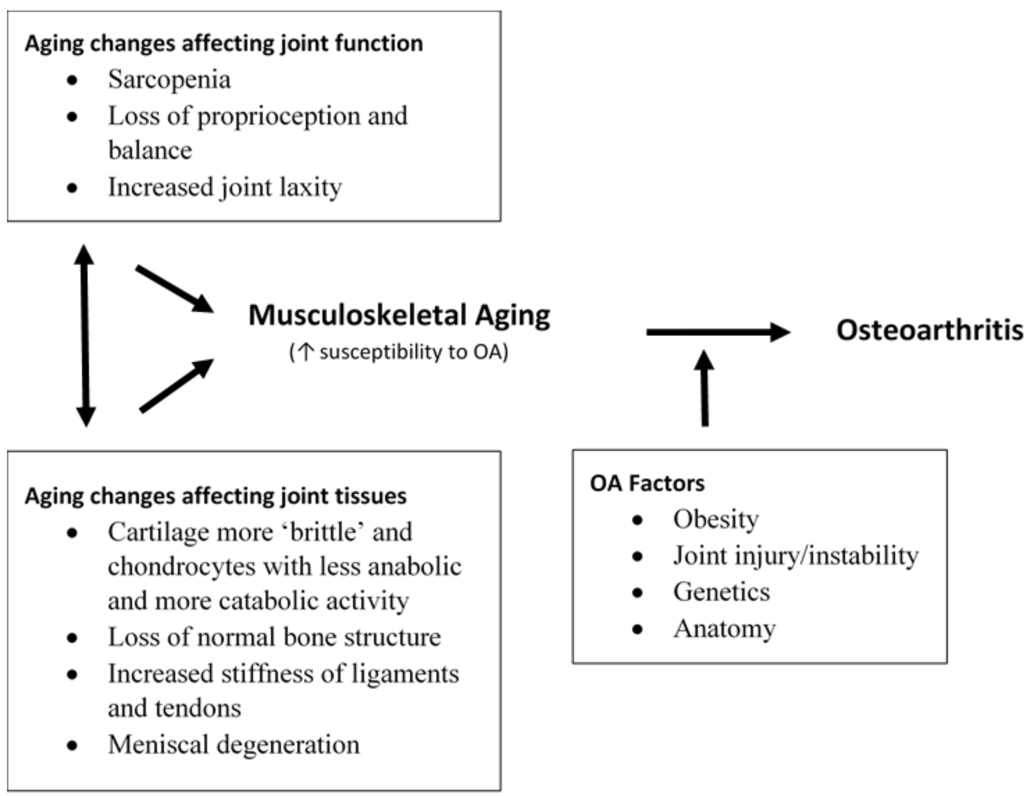


Figure 2.7 Relationship between musculoskeletal aging and the development of osteoarthritis. Adapted from Anderson & Loeser, 2010.[55]

As a leading cause of disability in Canada, osteoarthritis presents a significant economic burden, which is expected to grow exponentially over the next 30 years. The annual direct and indirect costs of arthritis (both osteoarthritis and rheumatoid arthritis) are in excess of $6 billion.[73] Recent estimates suggest that the total economic cost of arthritis exceeds $33 billion annually and this is projected to grow to more than $894 billion by 2030.[74]

Osteopenia/Osteoporosis

Osteoporosis is characterized by low bone mass along with changes to the bone micro-architecture that together, increase bone fragility and susceptibility to fracture.[69,75] Age-related deterioration in bone composition, structure and function leads to a predisposition to osteoporosis, particularly in women. The loss of bone mass (osteopenia), and an associated reduction in bone strength occurs when the normal processes of bone remodeling become unbalanced in favor of bone resorption.[76,77] Aging, along with several intrinsic and extrinsic factors all impact the rate of decline in bone loss and are outlined in Table 2.3.[76]

Table 2.3 Intrinsic and extrinsic factors affecting bone mass.[76]

Intrinsic Factors	Extrinsic Factors
• Age • Genetics • Peak bone mass accrual in youth • Cellular changes • Hormonal, biochemical, & vascular status	• Nutrition • Physical activity • Comorbidity • Drugs

Age-related bone loss is a complex process, resulting from multiple cellular level changes affecting trabecular bone, cortical bone and bone marrow.[77,78] The onset and triggers of age-related bone loss (outside that related to menopause) remain poorly understood.[76] Bone remodeling is a lifelong continuous cycle between osteoblasts (new bone deposition) and osteoclasts (bone resorption). After reaching peak bone mass and size early in the third decade, the rate of bone turnover slows, and bone mineral density begins to decline by approximately

0.5% per year, even though serum levels of estrogens are still within the normal range.[78] In women, the menopausal transition is associated with a period of accelerated bone loss (2% to 3% per year) that may persist for up to 10 years post-menopause.[76,79] The overall consequences of the shift in remodeling favoring resorption are thinning of cortical and trabecular bone, increased cortical porosity, and loss of trabecular connectivity, all of which reduce bone quality and bone strength.[76] The mechanisms involved in this process are summarized in Table 2.4.

Table 2.4 Mechanisms of age-related bone loss[76]

Mechanism	Result
Secondary hyperparathyroidism • Vitamin D deficiency impairs calcium absorption, stimulating increased parathyroid secretion • Chronic negative calcium balance due to age-related reductions in dietary intake • Impaired renal function • Use of diuretics • Estrogen deficiency	• Decreased osteoblastogenesis (vitamin D) • Increased osteoclastic activity leading to cortical bone loss
Sex steroid deficiency Women • Decreased serum estradiol levels at menopause Men • Decreased serum testosterone • Decreased serum estradiol levels*	• Increased osteoclast formation and osteoclastic activity
Increased adipogenesis in bone marrow • Age-related changes in recruitment of mesenchymal stem cells, release of key growth factors, activation of transcription factors, oxygen tension and blood supply in the bone marrow	• Differentiation of stem cells into adipocytes at the expense of osteoblasts

* Estrogen deficiency is more strongly correlated with bone loss than testosterone loss in aging men

Osteoporosis is a silent disease, often undiagnosed and asymptomatic until an incident fracture occurs, typically as a result of low-energy trauma.[69,80] Osteoporotic (or fragility) fractures are significantly more common in women than men, accounting for 80% of all fractures in women over the age of 50 years.[69,81] The vertebrae, femoral neck (hip) and distal radius are highly susceptible to fracture in older adults with osteoporosis. Vertebral and hip fractures, in particular, present a significant issue for older adults. Vertebral compression fractures can lead to height loss, kyphosis and significant pain, with the potential to impair pulmonary or gastrointestinal function and/or severely limit a person's ability to carry out activities of daily living such as bathing, dressing, or walking independently.[56] Hip fractures are associated with significant long-term morbidity, with fewer than 50% of older adults experiencing a full, functional recovery and approximately 25% residing in long-term care facilities for a year or more following a hip fracture.[69,82] Recent Canadian studies have shown that both hip and vertebral fractures are associated with increased mortality (adjusted hazard ratios of 2.7 – 3.2) in the first (hip) and second (vertebral) year following fracture.[83,84] Morin et al (2011) found that in certain age groups (women aged 50-69; men aged 60-69), the relative risk of death remained elevated beyond five years. These findings suggest that hip and vertebral fractures may have long lasting effects that signal or induce a progressive decline in health, eventually leading to death.[83,84]

In 2009, approximately 19% of Canadian women and 3.5% of Canadian men aged 50 years and older were diagnosed with osteoporosis while at age 70 years and older, 31% and 6.5% of women and men, respectively reported having been diagnosed.[25] The direct and indirect costs of osteoporosis are substantial, totaling more than $2.3 billion as of 2010. If the proportion of people assumed to be living in long-term care facilities due to osteoporosis is factored in, the cost rises to $3.9 billion.[85]

2.1.4.3 Metabolic function and health

Beginning around age 25–35 years, there is a slow and progressive decline in the levels of most hormones, brought about by decreased hormone synthesis along with a loss of hormone receptors.[86] Circadian rhythmicity is also altered in a slow but progressive manner, often resulting in disturbances to the sleep-wake cycle.[87,88] Consequently, overall endocrine function declines and homeostatic regulation across all physiological systems is diminished.[89] With regards to metabolic function, the key age-dependent changes include physiological declines in sex hormones (estrogens and androgens), growth hormone (GH), and insulin-like growth factor-1 (IGF-1), insulin resistance and changes in body composition.[89]

At mid-life, around age 35-40 years, circulating testosterone levels in men begin to decline by 1%-3% per year, while in women, estrogen levels decrease by an average of 80% during the first year of menopause.[90] Serum androgen levels in women and estrogen levels in men also decrease with age, although their biological roles in these instances are less understood.[90] The declines in estrogens and androgens experienced by women during the menopausal transition are relatively sharp and rapid compared to those experienced by men; however, in each instance, decreased levels of sex hormones are associated with increased vulnerability to disease in hormone-responsive tissues including muscle, bone and brain tissues.[91]

By age 70, levels of GH have declined to approximately 20% of the levels at age 30, a decrease followed by a concomitant drop in levels of IGF-1.[89,92] Growth hormone and IGF-1 signaling is critical in the regulation of protein synthesis and glucose metabolism.[90] While there is clear evidence of the contribution of the age-related decrease in GH/IGF-1 to many aspects of aging including: the accumulation of fat mass, cardiovascular dysfunction, and declines in cognitive function, immune function, cellular protein synthesis, and muscle mass considerable, debate about the role of GH/IGF-1 in aging continues, particularly in light of recent data showing that reduced GH/IGF-1 signaling is associated with anti-aging effects including a decreased risk of cancer, and increased longevity.[90,93-95]

There is great interest in the therapeutic potential of GH (and testosterone/estrogens) supplementation to counteract the age-related changes in body composition and metabolism in both healthy and frail older adults; however equivocal research findings and ongoing concerns about the safety and efficacy of long term GH and sex steroid hormone therapies contribute to the ongoing controversy in this area.[87,90,92,95,96]

Changes in Body Composition

Aging is associated with important changes in body composition and metabolism. Between the age of 20 and 70 years, there is a progressive increase in adiposity, which subsequently may continue to increase, decrease or remain unchanged.[89,97] Concurrent sarcopenic changes in skeletal muscle resulting in a progressive decline in fat-free mass of about 40% mean that even if a stable weight is maintained, the percentage of body fat will increase.[36] Age-related changes in body fat distribution are also evident, with a shift towards increased accumulation of visceral fat.[89] Visceral fat is hypothesized to pose a greater risk for the development of insulin resistance, metabolic syndrome and cardiometabolic diseases than other fat depots (e.g. subcutaneous, intramuscular) due to its anatomical location, high lipolytic rate and secretion of pro-inflammatory cytokines from adipocytes (adipokines).[98] These adipokines, including leptin, tumor necrotizing factors, and various growth factors, are thought to play a critical role in many disease pathologies by promoting angiogenesis, inflammation, cell proliferation and insulin resistance.[98]

Insulin Resistance

Insulin plays a critical role in maintaining glucose homeostasis by stimulating glucose uptake in insulin-sensitive tissues, inhibiting fatty acid release from adipose tissue, and decreasing hepatic production of glucose. Aging is associated with reduced sensitivity to the metabolic effects of insulin, resulting in a compensatory increase in insulin secretion by pancreatic β-cells. Over time, worsening insulin resistance and/or beta cell deterioration may lead to a progressive decline in glucose tolerance and the development of T2D (Fig. 2.8).[99-101] Impaired glucose tolerance is commonly observed in older adults, even among those who are not obese. In non-obese older adults, the principal defect appears to be impaired glucose-induced insulin secretion rather than insulin resistance.[100] Whether increased insulin resistance of older adults is intrinsic to aging *per se* or is the result of age-associated changes in lifestyle factors is the subject of some debate.[100] Although there is strong genetic component to insulin resistance, that environmental and lifestyle factors play a significant role is without question. The interaction between key factors in the development of insulin resistance is shown in Figure 2.8.[36,99]

Insulin resistance is one component of metabolic syndrome – a highly prevalent condition characterized by a constellation of abnormalities including abdominal obesity, hypertension, and dyslipidemia. Through its effects on lipid metabolism and endothelial function, insulin resistance is implicated in the development of both dyslipidemia and hypertension, in addition to T2D.[89] Furthermore, the association of insulin resistance with reduced skeletal muscle strength, reduced protein synthesis and accelerated muscle loss leads to the potential of an ongoing cycle of metabolic dysfunction and skeletal muscle loss wherein insulin resistance is both caused by and a contributor to the development of sarcopenia.[89]

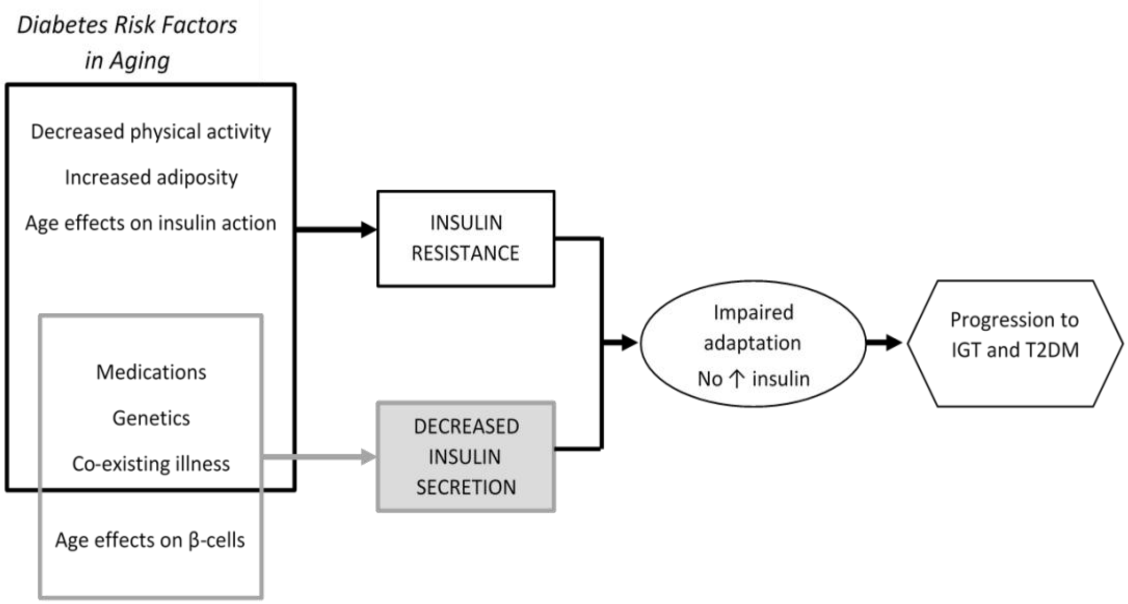


Figure 2.8 Interaction of genetic, lifestyle and aging influences on the development of T2D (Adapted from Chang & Halter, 2003)[99]

The age-related hormonal, morphological and metabolic changes discussed above significantly impact the health of older adults through their strong association with obesity, T2D, and cardiovascular disease. The social and economic consequences of obesity and diabetes are far-reaching and substantial. Since 1998, the prevalence of diabetes has steadily increased in all age groups, but particularly among adults aged 50 years and older.[102]. In 2008, the prevalence of diabetes among older Canadians ranged from 8.4% in the 50-54 year age group to approximately 25% among those aged 75 to 84 years, after which the prevalence declined to approximately 21%.[102] Overweight and obesity is also highly prevalent in this population, with approximately 40% of seniors classified as overweight and 30% classified as obese in 2008. Between 2000 and 2008, the annual economic burden of obesity in Canada increased by $735 million and is now estimated to be between 4.6 billion and 7.1 billion per year.[103] While difficult to determine, the direct and indirect costs associated with diabetes were estimated to be $12.2 billion in 2010 and are projected to increase by another $4.7 billion by 2020.[103,104]

2.1.4.4 Cancer

Cancer is a disease of aging – the incidence of cancer is 12-36 times higher in individuals aged 65 years or older than in individuals aged 25-44 years.[105,106] In Canada, 88% of all new cancer cases are diagnosed in people over 50 years of age, with 43% of new cases occurring in people aged 70 years and older.[107]

Cancer is characterized by uncontrolled cell proliferation, whereby cells become unresponsive to stimulatory and inhibitory signals that normally regulate cell growth and division. The growth of these cells is left unchecked, leading to tumor growth and malignancy.[108] The etiology of cancer is multifactorial with contributions from both genetic and environmental components. The prevailing hypothesis is that cancer results from the sequential accumulation of genetic mutations in genes critical to tumorigenesis.[106] This hypothesis lends support to the idea that the increased incidence of cancer in older adults reflects the time needed to accumulate a sufficient number of mutations in cancer-critical oncogenes and tumor suppressor genes.[109] Two additional mechanisms may also contribute to the strong association between age and cancer: increased susceptibility of aging cells and tissues to environmental carcinogens and cancer-promoting alterations in the body environment, such as immune senescence and premature senescence of fibroblasts and stromal cells.[109-111] Although cancer is a genetic disease in the sense that all cancers are caused by genetic mutations, fewer than 10% of all cancers can be attributed solely to an inherited genetic mutation.[107] Most cancers develop in genetically susceptible persons exposed to environmental carcinogens. Tobacco use, excessive caloric intake, low intake of fruits, vegetables and whole grains, obesity, infections radiation, stress, lack of physical activity and environmental pollutants have all been shown to increase the risk of developing cancer.[107,108]

Cancer now accounts for 30% of all deaths in Canada, making it the leading cause of death.[107] The most common cancers in older men are cancers of the prostate, lung, colon and rectum while cancers of the breast, lung, colon, rectum, and uterus are the most common cancers in older women.[107] The economic costs associated with cancer are substantial. In 2005, cancer was the fourth-costliest disease in Canada with direct and indirect costs totaling $17.4 billion.[107]

2.2 PHYSICAL ACTIVITY AND HEALTH

The groundbreaking work of two renowned epidemiologists[112,113] – Dr. Jeremy Morris, who examined coronary heart disease and occupational physical activity in double-decker bus conductor in the 1950's, and Dr. Ralph Paffenbarger, with his landmark studies of physical activity and cardiovascular disease in the College Alumni Health Study in the 1970's– who's contributions built a foundation for over sixty years of research that has shown, unequivocally, that regular physical activity increases longevity and decreases risk of chronic disease morbidity and mortality.[32,40]

In large part due to the pioneering work of Morris, Paffenbarger, and their colleagues, physical inactivity was recognized in the early 1990's as a major independent modifiable risk factor for CVD by the American Heart Association and the Heart and Stroke Foundation of Canada.[112-115] Since that time, several comprehensive consensus documents, reports and reviews summarizing and synthesizing the available research have been published. In 1994, the full proceedings of the 2nd International Consensus Symposium on Physical Activity, Fitness and Health, including a consensus statement by the world's leading researchers assessing the level and quality of evidence, was published in a 1000-page monograph.[116] Shortly thereafter, in 1996, the United States Department of Health and Human Services (USDHHS) released perhaps the most influential policy document to date: *Physical Activity and Health: A Report of the Surgeon General*.[38] These two documents represent the earliest and most influential large-scale documents summarizing the health benefits of physical activity. *Canada's Physical Activity Guide to Healthy Active Living* was released in 1998[117], followed shortly thereafter by versions tailored to older adults (1999)[118] and children and youth (2002)[119,120]. Several comprehensive reviews of literature have been published in subsequent years, building on the strong evidence base provided by the two benchmark publications.[32,39,40,121-125]

2.2.1 Concepts and Definitions

Physical activity (PA) is a complex and multidimensional behaviour and as such, is often described and defined in different ways in the literature depending on the focus of the research in question. Broadly speaking, *physical activity* can be defined as "bodily movement produced by skeletal muscles that requires energy expenditure" that produces overall health benefits.[126,127] Physical activity is an umbrella term encompassing all movement carried out in daily life including that associated with leisure-time pursuits (sport, exercise, and household tasks), work and transportation.[126,128] Distinctions are sometimes made in the literature between leisure-time, occupational and transportation-related PA, but very frequently, they are not. Likewise, researchers may distinguish between PA and exercise; however, these terms are also often used interchangeably. *Exercise* is a subset of PA that is "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness."[127] While PA is a behavior, *physical fitness* is a state characterized by one's "ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies."[126] It comprises a set of attributes that include cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility. With the emergence of sedentary behaviour as a new area of research, there has been greater recognition of the need to distinguish between it and physical inactivity in research studies.[129,130] Thus, *sedentary behaviour* is defined as "any waking behaviour characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" while *physical inactivity* denotes a level of moderate to vigorous PA that is insufficient for maintaining good health.[126,129,130]

2.2.2. Physical activity, aging and health

Older adults frequently identify the primary motivation to be physically active as the desire to maintain functional fitness in order to remain independent and there is substantial evidence to show that regular PA impacts the aging process in a positive way.[32] There are four pathways through which the effects of PA are apparent: (1) slowing of the biological aging process; (2) modification of risk factors for chronic disease; (3) alteration of disease progression in conditions that are already present; and (4) indirect effects on other modifiers of disease, such as psychosocial functioning.[131]

Although declines in the structure and function of the body's tissues are an inescapable consequence of aging, there is extensive evidence that PA can delay the onset of these changes and minimize the extent to which they occur.[32,132,133] Age-related declines in physical function, particularly those related to the cardiovascular and musculoskeletal systems, accrue insidiously over many years without much effect on daily life.[131] However, these subtle changes may eventually leave the 'average' older adult with a functional capacity limited enough to affect their quality of life and ability to live independently.[44]

As outlined in the previous section, aging is associated with changes in cardiovascular structure and function that lead to a steady decline in maximal heart rate, impaired compliance with diastolic filling, incomplete emptying in systole, and autonomic dysregulation, all of which negatively affect cardiovascular performance through their impact on stroke volume, ejection fraction, and cardiac output.[133] Declines in muscle mass, strength, and endurance as a result of sarcopenia and aging-related changes in protein synthesis and mitochondrial function can further compound these issues, resulting in significant declines in aerobic power and endurance.[32,133] Maximal aerobic power declines throughout adulthood, beginning around 25 years of age. After the age of 50 years, losses can average 0.4-0.5 $ml \cdot kg^{-1} \cdot min^{-1}$per year, equivalent to 5%-10% per decade.[32,49,133] Longitudinal studies have shown that the decline accelerates markedly with age, from ~5% per decade in the third and fourth decades to more than 20% by the eighth and ninth decade.[32] By age 80-85 years, maximal aerobic capacity in sedentary individuals often approaches 15-20 $ml \cdot kg^{-1} \cdot min^{-1}$.[32,133,134] At this level, the degree of exertion required to carry out many activities of daily living (ADLs) may be sufficient enough to create a situation which may threaten a person's ability to live independently. For example, many self-care activities, such as dressing, require an oxygen uptake approximating 9 $ml \cdot kg^{-1} \cdot min^{-1}$ (~2.5 METS, where 1 MET=3.5 $ml \cdot kg^{-1} \cdot min^{-1}$). An older adult with a maximal aerobic capacity of 15 $ml \cdot kg^{-1} \cdot min^{-1}$ would therefore be working at 60% of their maximum, a level within the aerobic training zone, simply to get dressed.[32,135] Sustaining this level of intensity (or greater) for much of the day would result in ongoing fatigue, likely leading to a reduction in some activities. A vicious cycle then follows where reduced activity and the slowing walking speeds lead to a progressive decline in fitness, other ADL become increasingly difficult and are subsequently discontinued, culminating in the loss of independence.[32,131] Figure 2.9 describes the relationships between age, chronic disease, lifestyle practices and functional ability in later life.

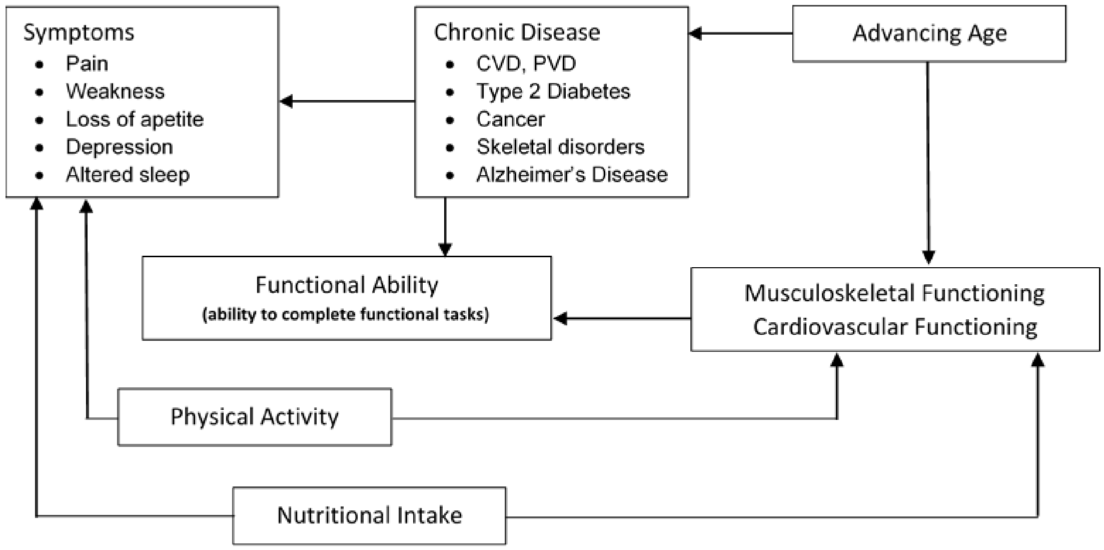


Figure 2.9 Relationships between age, chronic disease, lifestyle practices and functional ability in later life. Adapted from: Topp et al, 2004[14]

There is substantial evidence to suggest that as much as 50% of the decline in cardiorespiratory endurance is not due to aging per se, but rather to progressive inactivity, changes in body composition, and peripheral and cardiac muscle deconditioning.[32,133,134] The cardiovascular and musculoskeletal adaptations in response to regular aerobic and resistance training exercise in older adults run counter to the effects of aging on these systems and the degree of change is, for many adaptations, similar to that seen in younger adults.[32,131] Thus, regular moderate PA can markedly attenuate many decrements in exercise capacity that would otherwise occur with aging.[131] Even in sedentary older adults with functional limitations, the initiation of regular PA that includes aerobic and resistance activities can result in profound improvements in performance.[32]

The health benefits of PA and risks associated with inactivity are well established in the literature. In addition to its strong inverse association with all-cause morbidity, mortality and cardiovascular disease, PA has been shown to have a substantive role in the primary, secondary and tertiary prevention of many chronic diseases and conditions. In addition to the previously described improvements in cardiovascular functioning, PA has been shown to elicit improvements in blood pressure, congestive heart failure (CHF), lipid profiles. The incidence of T2D is lower among older adults who exercise, and for those who have been diagnosed with T2D, PA improves glycemic control, decreases hemoglobin A1C levels, and improves insulin sensitivity. Physical activity also positively affects bone health. Bone loss is minimized in post-menopausal women, and the risk of fractures and falls is reduced. In older adults with arthritis, PA helps to improve joint by increasing the strength of muscles around the affected joint and alleviating pain. Regular PA is also associated with a reduced incidence of colon and breast cancer. Additional neuropsychological benefits, including decreased anxiety and depression, improved sleep quality and cognitive function, and positive well-being and quality of life are of particular relevance to older adults.[32,40,121,125,132,136-141]

There is clear evidence of a dose-response relationship between PA and health status, whereby higher levels of PA are associated with greater health benefits.[125,136,142] However, uncertainty remains about the optimal and minimum 'dose' of PA necessary to attain health benefits.[125] Nevertheless, even small increases in PA are associated with significant reductions in health risk, especially in individuals who transition from being predominantly sedentary to beginning some level of activity.[40,142]

The far-reaching beneficial effects of PA come about as a result of its acute and chronic effects on several biological mechanisms (Table 2.5).[40] Direct adaptions include a reduction in systemic inflammation, enhanced insulin sensitivity and improved glucose homeostasis. Physical activity also reduces blood coagulation, enhances blood lipid profile, improves autonomic tone

Table 2.5 Chronic conditions which can be prevented or ameliorated with PA[39,40,121,125,138,140]

Chronic condition	Risk factor	Proposed Mechanism(s) of Action
Cardiovascular disease	hypertension dyslipidemia obesity	• ↑ fibrinolysis /↓ thrombocyte aggregation – ↓ blood coagulation • ↑ endothelium dependent vasodilation – ↑ coronary blood flow • improved autonomic tone • improved blood pressure regulation – ↓ sympathetic tone and catecholamine levels – ↑ endothelium dependent vasodilation – ↓ levels of c-reactive protein (chronic inflammation) • enhanced lipid lipoprotein profiles (↓ triglycerides, ↑ HDL cholesterol, ↓ LDL/HDL ratio) – ↑ enzyme activation leading to enhanced lipid metabolism in the muscle • enhanced myocardial function, systemic arterial compliance, stroke volume • reduced cardiac muscle atrophy due to ↓ inflammation
Type 2 diabetes	insulin resistance glucose intolerance dyslipidemia obesity	• ↓ visceral adiposity • improved weight control • enhanced insulin sensitivity and glucose homeostasis – ↑ insulin signaling, glut-4 content, enzyme activity – ↓ release and ↑ clearance of free fatty acids – ↑ muscle capillarization and blood flow • improved endothelial function – ↑ shear stress on vessel wall stimulates release of nitric oxide, inducing smooth muscle relaxation and vasodilation
Cancer	obesity low bowel immotility sex hormone profile	• altered hormone function, insulin and insulin-like growth factors, enhanced immune function, ↓ free radical generation • ↓ gastrointestinal transit time • improved body composition • ↑ fitness and muscle strength, decreasing fatigue
Obesity		• ↑ energy consumption by tissues • ↓ insulin resistance • ↑ lipolysis
Osteoarthritis		• ↑ muscle strength, improving joint stability • ↓ weight
Osteoporosis	low bone density	• ↑ bone cross-sectional area • ↑ bone mineral density • ↑ muscle strength and balance, reducing risk of falls
Frailty	sarcopenia muscle weakness poor balance neuromuscular deficits	• ↑ muscle mass, strength power and balance

and endothelial function. Furthermore, PA has direct benefits for reducing resting blood pressure, improving coronary blood flow, and enhancing cardiac function.

Indirectly, improvements in body composition and weight control brought about by PA may also positively impact a number of chronic conditions.[40,121,125] The direct effects of PA on the many pathophysiological changes central to multiple chronic diseases augment physiological function beyond that which would be achieved by standard disease management strategies (e.g. pharmacological or dietary).[125,131] A recent comprehensive review of the literature pertaining to PA and aging concluded that PA is "likely the best non-pharmaceutical remedy to maintain health and functional independence.[32,143]

The World Health Organization has suggested that age 50 marks a point in middle age at which the benefits of regular PA are most relevant in avoiding, minimizing, and/or reversing many of the physical, psychological, and social hazards which often accompany advancing age.[143] Furthermore, most individuals, regardless of health status and/or disease state, can realize positive effects of a physically active lifestyle. For older adults, the majority of whom (>80%) live with at least one chronic condition, the secondary and tertiary benefits of PA are equally as important as its role in primary prevention.

Successful aging depends on more than good physical health and functional capacity.[141] Psychological well-being, mutually supportive social relationships and contacts, self-reliance and self-determination, and social roles and contributions are also important to remaining in good health over the life course.[7,141] Over and above its physiological benefits, regular PA also confers a number of psychological and social benefits, including improved psychological well-being and mental health (e.g., through enhanced relaxation, reduced stress, anxiety and depression).[32,40,125,132,141] A physical active lifestyle also provides opportunities to enhance social networks and interactions, and helps to foster stimulating environments necessary to develop positive new roles and maintain an active role in society.[132,144]

2.2.3 Physical Activity Levels of Older Adults in Canada

Recommendations for PA continue to evolve as new evidence emerges about the 'dose' of PA necessary to obtain optimal health benefits.[145] The current Canadian PA guidelines for older adults were revised and released in January 2011.[39,142] The guidelines include four recommendations:

1. To achieve health benefits and improve functional abilities, adults aged 65 years and older should accumulate at least 150 min of moderate- to vigorous-intensity aerobic physical activity per week, in bouts of 10 min or more.
2. It is also beneficial to add muscle- and bone-strengthening activities that use major muscle groups, at least 2 days per week.
3. Those with poor mobility should perform physical activities to enhance balance and prevent falls.
4. More physical activity provides greater health benefits.

According to self-reported estimates, approximately 51% of Canadian adults aged 45 to 64 years and 46% of Canadian seniors are physically active.[146] However, recently released objective PA data from the Canadian Health Measures Survey (CHMS) indicate that the vast majority of middle-aged (40–59 yrs.) and older adults (60–79 yrs.) are inactive, with fewer than 15% accumulating the recommended 150 minutes per week of moderate-vigorous PA.[147] Among adults aged 60 years and older, slightly more men (13.7%) than women (12.6%) achieved the recommended level of PA, spending on average 12-17 minutes per day in moderate-to-vigorous

PA. This age group is also the most sedentary, spending approximately 10 hours/day in sedentary pursuits outside of normal sleep time.[147]

In recent years, sedentary behaviours have emerged as a new focus of PA research and there is mounting evidence showing that sedentary behaviours have important health consequences, independent of moderate- to-vigorous-intensity PA levels.[142,148] However, sedentary behaviour guidelines for adults and older adults have yet to be developed for most nations, including Canada. In addition, guidelines addressing the unique needs of persons living with chronic conditions are also clearly needed.[142] The establishment of evidence-based guidelines in these two contexts would augment current PA guidelines, particularly for the older adult population.

2.3 HEALTH SERVICES UTILIZATION

Chronic diseases, as previously outlined, account for almost three-quarters of all deaths in Canada and are major causes of premature death and hospitalization. Combining direct medical costs ($38.9 billion) and indirect productivity losses ($54.4 billion), the total economic burden of the seven most common chronic illnesses (cardiovascular diseases, cancer, chronic respiratory ailments, diabetes, musculoskeletal disorders, diseases of the nervous system and sense organs, and mental illness), exceeds $93 billion a year.[57] There is increasing concern that as Canada's population ages, the increasing chronic care needs of older adults will place considerable strain on the health care system, both in terms of its capacity to meet an increasing demand for services and its ability to sustain the current level of service provision in the face of increasing costs.[30,149] Consequently, research examining the utilization of health care services and its determinants is of growing interest to governments and health services administrators as they seek to contain rising health care costs and allocate scarce resources in an efficient and effective manner.

Health care service utilization includes complex and multifaceted behaviors with many influences beyond those related to health and illness. Sociodemographic characteristics, culture, economics, personality, perceptions, access, attitudes and beliefs, and social roles are just a few examples from a long list of non-health factors that influence the decision to seek health care, the type and volume of services used and the outcome of health-related services.[150] Several models that integrate multiple domains of predictors have been developed to describe the relationships between the various factors that influence an individual's use of health services, the most influential being the Andersen-Newman social-psychological model, also known as the Behavioral Model of Health Services Use.[151-153]

2.3.1 The Behavioral Model of Health Services Use

The Behavioral Model of Health Services Use (BMHSU), first proposed by R.E. Andersen in 1968,[154] initially sought to identify those factors influential to the use of health services and to define and assess equitable access to health care.[155] A later adaptation of this model, published by Andersen & Newman in 1973, remains the prevailing behavioral model of health services utilization in the literature today.[151-153] Over the last 50 years, this model has been tested and adapted for use in various populations, evolving and expanding as researchers gained a better appreciation of the complexity surrounding the use of health services.[152,155,156] In Canada, this model has been used to compare the use of emergency room and other hospital services as well as those provided by physicians and allied health professionals[28,157-159]; evaluate access to health care services[160]; compare determinants of health care utilization between health care systems[161]; identify health services research priorities in specific populations[162], and examine caregiver intentions to use formal care services.[163]

As shown in Figure 2.10, Andersen's 1995 Behavioral Model presupposes that health outcomes (defined as perceived and evaluated health status, along with customer satisfaction) are the result of the integrated influence of four domains of individual and contextual determinants of health services use, which Andersen describes as "emphasizing the dynamic and recursive nature of health services utilization".[155] A more detailed description of the BMHSU follows Figure 2.10. This conceptual framework was used to guide the selection of explanatory variables in the two studies comprising this thesis. It should be noted, however, that for the purpose of this thesis, the outcome of interest is health services utilization (health behavior) not health status (health outcomes).

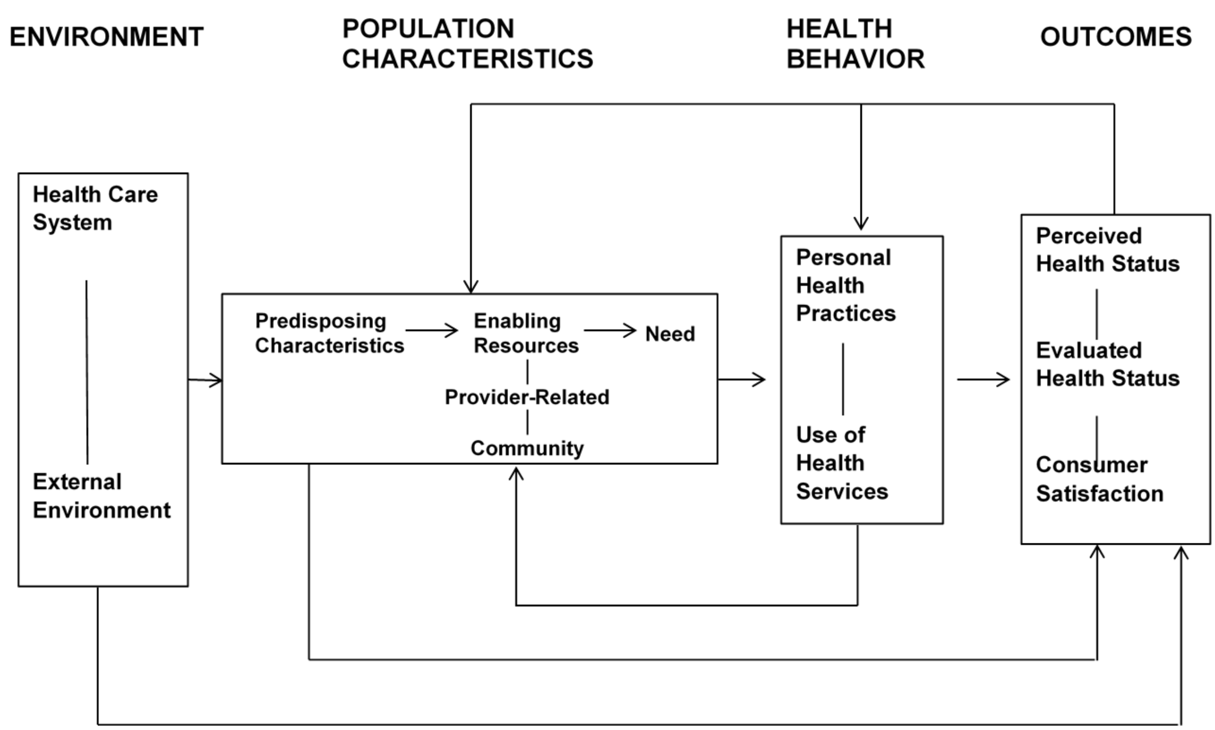


Figure 2.10 Behavioral Model of Health Services Use
(Adapted from: Andersen, 1995, Phillips et al, 1998)[155,156]

The conceptual framework developed by Andersen and colleagues uses a systems perspective to integrate a range of environmental, individual and provider-related factors associated with health services utilization.[156] Environmental variables include characteristics of the health care system and the external environment. Within the context of particular health system and political, economic, geographic and cultural environments, the BMHSU differentiates between predisposing, enabling and need-related population characteristics that influence the use of health services. Predisposing factors refer to the socio-cultural characteristics that influence an individual's propensity to use health services before they have a need to do so. These include demographic characteristics (age, gender), social structure (marital status, education, ethnicity), and health-related beliefs (factors related to a person's knowledge, attitudes and values related to health, illness and health services). Enabling factors are those conditions that facilitate or impede one's ability to obtain health care services, such as income level, health insurance coverage, accessibility of health care providers and facilities, type of municipality (urban/rural), employment, and family size. Individual factors that may be influenced by health service providers and provider characteristics that interact with characteristics of individuals are both types of provider-related variables. For example, whether or not a person has a family doctor (individual factor) and the gender of the health service provider (provider characteristic) may act along with community-level enabling factors, such as the availability of physicians in the community, to provide measures of the context within which health services utilization occurs.[156] Need factors include one's perceived and evaluated health, illness, and functional status. As might be expected, a person's health or illness level is the most salient determinant of health service use.[152,153] Population characteristics both directly influence and are influenced by personal health practices (diet, exercise, self-care) and health services utilization which, in turn, both directly influence and are influenced by health status outcomes. Feedback loops highlight the interrelationships between the components of this model, which are dynamic in nature.[155]

2.3.2 Physical activity and health services utilization in older adults

Given the importance of PA to both healthy aging and health status, there is increasing interest in the potential role of PA in reducing health services utilization and costs. As shown in Figure 2.10, the BMHSU provides theoretical support for an indirect relationship between PA and health services utilization, such that PA influences and is influenced by population characteristics, including health need, which also directly influence health services utilization. The model does not, however, overtly suggest the possibility of a direct relationship between PA and health services utilization.[156] Until now, the relationship between PA and health services utilization has received relatively little attention in either the PA or the health services utilization literature. The majority of the published studies examining the relationship between PA and health services utilization are based on data from the HMO and Medicare systems in the United States, or on data from Europe. Canadian data examining associations between PA, health services utilization and health care costs is quite limited.[164,165] In fact, a recent review of trends in PA research suggests that just 2% of all PA research in Canada is health services related.[164]

The earliest Canadian research in this area was published by Dr. Roy Shephard in the early 1980's, with his study of employee fitness and lifestyle programs and their influence on medical care costs.[166] Health expenses of employees were compared between two similar insurance companies for the year prior to and the year in which one company instituted an employee fitness program. Once the fitness program had been instituted, employees at the test company tended to have fewer hospital days and fewer medical claims of all types compared to those of the control company.[166]

Close to twenty years after Shephard's early work in this area, Katzmarzyk and colleagues published the first of two widely cited studies on the economic burden of physical inactivity in Canada.[167,168] Using a prevalence-based approach, Katzmarzyk and colleagues estimated that in 1999, approximately $2.1 billion, or 2.5% of the total direct health care costs in Canada could be attributed to physical inactivity.[167] They further showed that the highest costs associated with physical inactivity were associated with CHD ($891 million), osteoporosis ($352 million), stroke ($345 million) and hypertension ($314 million), concluding that a 10% reduction in physical inactivity would result in a reduction of approximately $150 million annually in direct health care costs.[167] In an update published in 2004, Katzmarzyk & Janssen again estimated the economic burden of physical inactivity, as well as that associated with obesity, this time also including estimates of indirect and total health care expenditures.[168] They found that the total economic burden of physical inactivity was $5.3 billion, with $1.6 billion and $3.7 billion spent on direct and indirect costs (in 2001 dollars), respectively. As was the case in Katzmarzyk's earlier study, the three most expensive chronic diseases were CHD ($1.7 billion), osteoporosis ($1.5 billion) and stroke ($765 million).[168] In 2012, Janssen published an update of the 1999 Katzmarzyk et al paper, making use of newly available objectively measured physical inactivity prevalence estimates.[169] The estimated direct, indirect and total costs (in 2009 dollars) of physical inactivity were $2.4 billion, $4.3 billion, and $6.8 billion, respectively, accounting for 3.6%-3.8% of overall health care costs in 2009. In this study, the chronic diseases with the highest costs attributable to physical inactivity were CHD ($2.7 billion), type 2 diabetes ($1.4 billion), and stroke ($1.1 billion). These cost estimates are substantially higher than those in

2001, primarily as a result of 3 factors: inflation, population growth, and reliance upon objectively measured PA data.[169]

These three studies all employed a prevalence-based approach to estimate the health care costs attributable to physical inactivity. Estimates of population attributable risk (PAR%) were calculated for chronic diseases and conditions associated with physical inactivity based upon summary relative risk estimates derived through meta-analytical methods and the population-level prevalence of physical inactivity in Canada. These PAR% values were then applied to disease-specific direct and indirect health care costs published by Health Canada in order to determine the portion of these costs that were attributable to physical inactivity.[167-169] While the picture of the economic burden of physical inactivity presented in these studies is compelling, it is limited in three important ways. First, these studies use an indirect cost-of-illness approach based on population prevalence and relative risk estimates to ascertain costs. In relying on aggregated population-level as opposed to individual-level data, these studies are unable to account for additional factors which may also contribute to costs.[170,171] Secondly, physical activity also likely influences the use of health services above and beyond its association with the lifestyle related chronic diseases and conditions considered in this study. Therefore, the impact of physical inactivity on health care expenditures is likely underestimated in these studies.[167,169,171] Lastly, these studies are not able to provide specific insight into where and how health care costs are incurred, which is an important consideration from a health policy and resource management perspective.

There is a growing body of literature that makes use of person-level data to examine the association between PA and health services utilization and/or health care costs; however, there are few studies that have specifically considered the older adult population[170,172-179], particularly in the Canadian context.[172,180-182] As a population, older adults typically have greater interaction with and dependency on the health care system than younger populations.[149] Furthermore, substantial structural differences exist between health care systems of different nations and even where systems have similar methods of public financing and universal coverage, differences in in culture, illness behavior, ethnicity, and access limit the extent to which comparisons can be made. Therefore, the overall generalizability of studies of health services utilization remains an outstanding question and the lack of Canadian studies examining the relationship between PA and health care utilization in older adults is an important gap in this literature.[165,177]

In reviewing the literature in this area, thirty-one studies specifically examining relationships between PA and health services utilization in an older population were identified and of these, eight were carried out using Canadian data. A summary of available literature is provided in Table 2.6. Key findings in the Canadian literature, as they pertain to different types of health services utilization, are outlined below.

Table 2.6 Summary of literature on the association of physical activity (PA) and health care utilization and/or costs in older adults

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Ackermann et al, 2003[183] (USA)	N=1,114 • 65 yrs. and older • Health maintenance organization (HMO) enrollees (1997-2000) • Participated at least once in the Lifetime Fitness Program offered as a health benefit • Age/sex matched comparison group	• Retrospective matched cohort • Examined differences in HCC/HCU between enrollees who did and did not participate in exercise program • HCC data from the HMO administrative decision support system	**Independent** • Participation in LFP physical activity benefit (yes/no) **Dependent** • HCC from index date until 31Dec 2000 − Inpatient hospitalization − Primary care visits − 3 summary cost variables Covariates included age, sex, health status, index date, baseline lifestyle, readiness to change, and pre-exposure HCC/HCU	• Average increase in total HCC was less in participants compared to controls (+$642 vs. +$1175; p=.05) • After adjusting for covariates, total HCC for participants were 94% that of controls • Those who attended LFP ≥1 time/wk. - total adjusted follow-up costs were 79.3% those of controls. • Adjusted follow-up risk of hospitalization was 4.9% lower in participants than controls
Ackermann et al, 2008[184] (USA)	N=1,188 • 65 yrs. and older • Health maintenance organization (HMO) enrollees (1997-2004) • Participated at least once in the EnhanceFitness (EF) physical activity benefit • Age/sex matched comparison group	• Retrospective matched cohort • Examined difference in HCC over 2 years and program effectiveness • HCC data from the HMO administrative decision support system	**Independent** • Participation in EF physical activity benefit (yes/no) **Dependent** • Change in HCC over 2 years − Inpatient hospitalization − Primary care visits − Specialty care visits Covariates included age, sex, previous arthritis visits, heart disease and diabetes indicator, baseline HCC and HCU, prevention score	• In year 2, EF participants adjusted HCC were $1,186 lower (p=.005) than for non-EF users • Differences partially attributable to lower inpatient costs (-$3,384; p=.02) • Those who attended EF 1 or more times per week had lower adjusted total HCC in Year 1 (-$1,929; p<.001) and Year 2 (-$1,784; p<.001) than non-EF users.

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Anderson et al 2005[170] (USA)	N=8000 • 40yrs and older • Stratified random sample of 8000 members of members of HealthPartners (Minnesota health plan) • 3 strata based on diagnosed CAD; diabetes; hypertension; dyslipidemia (ICD-9-CM) − 0/4 conditions − 1/4 conditions − 2 + conditions	• Retrospective cohort • Developed a predictive model of HCC Two sources of data • Survey data collected in 1995 • Data extracted from respondents' administrative claims between 1996 and 1999 • Charges standardized to 1997 dollars	**Independent** • Self-reported PA status Categorized as: − inactive, low active and active **Dependent** • Log of averaged annualized health care charges over a 4yr period • Included charges related to: − Physician' Inpatient, Outpatient Controlled for 5 covariates (age, sex, comorbidity, smoking & BMI)	• Inactivity not associated with HC charges in women • Inactivity and overweight/ obesity associated with 23% of all health care charges − Half of charges associated with inactivity were from groups aged 40-64 without chronic disease. • Those aged 65+ had the highest charges associated with inactivity – similar for those with and without chronic conditions
Andreyeva & Sturm, 2006[178] (USA)	N=8,788 • 50 to 69 years • Initial panel (1992) age eligibility was 51-61 yrs. • Data pooled across 4 waves of survey to increase sample size	• Prospective, cross-sectional and longitudinal • Health and Retirement Study • Examined how PA is associated with changes in health expenditure for a national sample of mid-life adults • Self-reported HCU. Expenditure data taken from HRS files developed by RAND • HCC measured over 2 yrs. following an assessment of regular PA	**Independent** • Self-reported PA based single question regarding participation in vigorous PA (yes-active/no-inactive) **Dependent** • Average annual HCC (2004 dollars) Adjusted for socio-demographic factors, health status, baseline HCC and health-risk behaviors	Cross-sectional analysis • Mean HCC were 33% higher for inactive vs. active (difference=$1,879; p<.01) Longitudinal analysis • Adjusted (health not included) mean HCC 13.2% higher in inactive (difference=$854; p<.05) • Adjusted (health included) mean HCC 7.3% higher in inactive (difference=$483; p>.05)

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Borzecki et al, 2005[176] (USA)	N=1397 • Men • Three age-based cohorts randomly selected from national Medicare database Intentional representation of women living in rural/remote areas	• Prospective cohort • Veteran's Health Study • Examined impact of health behaviors on HCU in a sample of male veterans • HCU measured for 12-month follow-up period • Data linkage between veterans' survey data and the VA administrative health database	**Independent** • Self-reported PA based adapted College of Alumnus Questionnaire − Classified as 'active' if they walked more than 2 blocks/day, climbed more than 2 flights of stairs/day or participated in MVPA in a typical week. **Dependent** Administrative HCU data for the 12-month study period • Inpatient stays • # of outpatient visits Controlled for sociodemographic factors (6), comorbidity, quality of life, non-VA insurance, disability	• PA was not significantly associated with hospital stays • Active veteran's had significantly fewer physician visits than inactive veterans • Adjusted analyses revealed no significant association between PA and physician visits
Brown et al, 2008[185] (AUS)	N=7,004 • Women aged 50-55 yrs. • Three age-based cohorts randomly selected from national Medicare database • Intentional representation of women living in rural/remote areas	• Cross-sectional, prospective cohort • Australian Longitudinal Study on Women's Health (ALSWH) • Examined relationships between combined categories of PA and BMI with health care costs in women • Data linkage between respondents survey data and Medicare administrative health database	**Independent** • Self-reported PA based on Active Australia items − PA score (MET·mins/wk.) categorized into 5-level variable − PA score >600 is equivalent to current guidelines (150 min/wk.) **Dependent** Administrative HCU data • Total # of annual Medicare claims • Annual cost of Medicare-subsidized services	• Mean annual HCC were 26% higher in sedentary compared to moderately active women • Mean costs were 43% higher for sedentary obese women than healthy weight moderately active women • Relative risk of "high" claims (≥ 15 claims/yr.) were lower for moderately/high active overweight women than sedentary, healthy weight women • Significant cost savings could be achieved if sedentary mid-age women could achieve low levels (60-150 min/wk.) of PA

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Buchner et al, 1997[186] (USA)	N=181 • 68 – 85 yrs. of age • Random sample of older adults enrolled in a large health maintenance organization (HMO) • Eligibility criteria included issues with gait and low knee extensor strength • 3 supervised exercise groups and 1 control group – Endurance training (ET) 30-35 min x 3 days/wk. at 75% HRR – Strength training (ST) 8 exercises/2 sets @50%-75% 1RM – ET+ST 20 min ET/1 set ST@75% 1RM	• Single-blinded, randomized control trial (RCT) with intention to treat analysis • 30-35 min x 3 days/wk. at 75% HRR • National Institute of Aging FICSIT (Frailty and Injuries: Cooperative studies of intervention techniques) • Tested the effect of strength and endurance training on gait, balance, physical health status, fall risk and HSU • HSU and cost data obtained from HMO administrative databases	**Independent** • Exercise group • PA measured 4 days/month via Caltrac activity monitors **Dependent** HCU in 12 months prior to randomization and post-intervention • # of outpatient visits • Costs of outpatient visits • Hospitalization (yes/no) • Costs of hospital use	• Outpatient visit rates were stable over time (~7 visits/year) in exercise participants but increased in control group (7.8 – 10.8 visits/yr.; p<.06) • No difference between groups in outpatient costs • Hospital use following intervention was similar between exercise and control groups, however: − Controls were more likely to spend more than 3 days in hospital (p<.05) − Hospitalized controls were more likely to have >$5000 in hospital costs.
Chen et al, 2008[187] (TAIWAN)	N=96 • 65-79 yrs. of age • Random sampling used to choose 4 experimental and 4 control communities • Systematic sampling used to identify 1,175 potential participants Lost to follow up = 20	• Prospective controlled trial • Evaluate the effects of a 12-week hospital-based walking training program on HSU • Self-reported HSU and cost utility analyses were used to test the economic effects of the walking program	**Independent** • Group (exercise (EG) vs. control (CG) **Dependent** Self-reported HCU data • # of hospitalizations • # of outpatient visits • # of ER visits	• Significantly fewer hospitalizations in EG following intervention. No hospitalizations in CG at any point. • No significant difference in change in outpatient visits between EG & CG • Increase in outpatient visits was significant in CG but not in EG. • No ER visits occurred pre- or post-intervention in either group.

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Courtney et al, 2009[188] (AUS)	N=128 • ≥ 65 yrs. of age • Targeted older adults with known risk factors for hospital readmission • Recruited within 72 hours of hospital admission with medical diagnosis	• 6-month RCT • Evaluate the effect of an exercise-based model of hospital and in-home follow-up care • Intervention included tailored exercise program and nurse-conducted home visit and telephone support commencing in hospital and continuing for 6 months after discharge • Data collected at 4 time points • Self-reported HSU and hospital medical records	**Independent** • Group (intervention (IG) vs. control (CG) **Dependent** Self-reported HCU supplemented by data from hospital medical records • # of ER readmissions • # of emergency GP visits • Length of hospital stay	• Significantly fewer ER hospital readmissions in IG compared to CG (22% IG vs. 47% CG, p=.007) • Significantly fewer emergency GP visits in IG compared to CG (25% vs. 67%, p<.001)
Davis et al, 2011[189,190] (CAN)	N=155 • Community-dwelling women aged 65-75 yrs.	• 12-month RCT of resistance training (RT) in older women (Brain Power) • Determine incremental cost-effectiveness and cost-utility ratio of 1/wk. or 2/wk. RT compared to 2/wk. balance and tone classes (control group -CG). • All classes were 60-min with a 10-min warm-up, 40-min core content and 10-min cool down • RT classes used a progressive, high-intensity protocol. • HSU data collected at 3-month intervals for 9-months. • Self-reported HSU with costs estimated based on existing cost models • A second study was published examining the sustained effects of this intervention.[190]	**Independent** • Intervention group (IG): – 1/week RT (IG) – 2/week RT (IG) – 2/week balance and tone (CG) **Dependent** Healthcare resource use and costs based on self-reported: • # visits to health professionals (including general practitioners, specialists, physiotherapists etc.) • # of visits, admissions or procedures carried out in a hospital • # of laboratory or diagnostic tests	**12-month findings** • Mean total healthcare costs were significantly lower for the intervention groups (both 1/wk. and 2/wk. RT) than the control group. **21-month findings**[190] • Although health benefits obtained during trial were not sustained, reduction in HCC was significantly greater in IG compared to CG • Hospital admissions were the main driver of total health resource utilization

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Davis et al, 2013[191] (CAN)	N=86 • Community-dwelling women aged 70-80 yrs. • Cognitively intact but self-reported memory difficulties	• 6-month RCT of resistance training (RT) in older women (Exercise for Cognition & Everyday Living - EXCEL) • Determine incremental cost-effectiveness and cost-utility ratio of 2/wk. RT, 2/wk. aerobic training (AT) compared to 2/wk. balance and tone classes (control group -CG). • All classes used same format as Davis et al, 2011 • Same measures as Davis et al, 2011	**Independent** • Intervention group (IG): – 2/week RT (IG) – 2/week AT (IG) – 2/week balance and tone (CG) **Dependent** Healthcare resource use and costs based on self-reported: • # visits to health professionals (including GP, specialists, physiotherapists etc.) • # of visits, admissions or procedures carried out in a hospital • # of laboratory or diagnostic tests	• Mean total healthcare costs were significantly lower for the RT and AT intervention groups than the control group.
Denkinger et al, 2012[192] (GER)	N=1,506 • Population-based • 65-90 yrs.	• Cross-sectional • ActiFE Ulm (Activity and Function in the Elderly in Ulm) Study • Examined the associations of formerly described and potentially new parameters influencing HCU in older adults in Germany • Self-report HCU data • Also assessed comorbidity, loneliness (0-10 scale), overall pain (0-10 scale), health-related quality of life (SF-12), social networks, cognition, depression, BMI	**Independent** • PA measured by accelerometry for 1 week – Ave. daily minutes of walking • Physical performance – 10-item instrument to assess ability in instrumental ADL **Dependent** Self-reported HCU in last 12 months • Contact with outpatient physician • Number of drugs (prescribed and over the counter) Length of hospital stay	• Over 95% of participants had at least 1 physician contact in previous 12-months – More than 65% contacted their physician more than twice • Approximately 20% experienced a hospital admission – < 5% stayed longer than 2 weeks • Lower levels of walking was one of the best predictors of HCU as measured by the number of drugs and number of physician contacts over 12-months • Other important predictors included: BMI, self-rated health, comorbidity, and male sex

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Holland et al, 2005[193] (USA)	N=504 • 65 years & older • 1 or more chronic conditions • Members of Medicare-managed care programs • Holders of CalPERS long-term care insurance policy	• Randomized control trial • 12-month study period • Participants randomized to Health Matters program or control group • Health Matters program: − Average of 11 contact hours with nurse-coach − Newsletters and information about recommended fitness and community programs − Mid-year in-person interview − Information provided to primary care physician − Counselling provided by a social worker available to participants	**Independent** • Self-reported weekly aerobic activity (min/wk.) • Self-reported weekly stretching activity (min/wk.) **Dependent** Administrative HCU provided by HMO • hospital claims • ER claims • Physician encounters	• No significant group differences in hospital use, long-term care benefit use or physician encounters in 12-month study period
Jacobs et al, 2013[194] (ISR)	N=2,069 • Representative sample of older adults born in 1920-1921) • Randomly selected from electoral register	• Longitudinal cohort • Jerusalem Longitudinal Cohort Study (1990-2010) • Examined effects of changing PA levels on ER visits and hospitalization at ages 78 and 85 • Data collected in 2 separate home visits • PA questionnaire adapted from Gothenburg 70-year-olds Study	**Independent** • Self-reported PA: How often are you physically active? 4 options: <4 hrs./week; ~ 4 hrs. /week; at least 1hr/day; vigorous sports at least twice/wk. • Dichotomized PA level (active/inactive) based on response: Inactive – < 4hrs/wk. Active – all other responses **Dependent** Self-reported HSU in 12-months preceding interview. • ER visits • Hospital admissions Dichotomized into: never/≥ 1 per year Adjusted for: sex, education, loneliness, functional dependence, cognitive impairment, depression, comorbidity, self-rated health, BMI, and smoking	• After adjusting for covariates, PA was associated − reduced likelihood of ER visits at age 78 yrs. - OR=0.49 (0.27-0.89) − reduced likelihood of ER visits - OR=0.72 (0.52-0.99) and hospitalization - OR=0.68 (0.48-0.98) Compared with those consistently active at ages 78 and 85 • initiating PA between ages 78 and 85 result in similarly lower likelihood of: − ER visits – OR=0.6 (0.23–1.56) − Hospitalization – OR=1.20 (0.48–3.02) • stopping PA or never being active between ages 78 and 85 resulted in increased likelihood of: − ER visits – OR=1.72(1.02–2.88); OR=2.18 (1.04–4.57) • hospitalization – OR=1.85 (1.06–3.23); OR=2.01 (0.92–4.4)

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Kemmler et al, 2010 (GER)[195]	N=246 • 65 years & older • Community-dwelling women	• Randomized control trial – Senior Fitness & Prevention (SEFIP) Study • Determine whether a single exercise program affects fracture risk, CHD risk factors, and health care costs • 18-month exercise intervention – compared high intensity exercise with low frequency wellness program • Exercise program consisted of two 60-min supervised group classes and two 20-min home training sessions • HCC data obtained from health insurance database for 6-months prior to and full 18-months of the intervention	**Independent** • Intervention group: – Exercise group vs. wellness control **Dependent** Administrative HCC data (excluding dental costs)	• At 18-months, HCCs per participant were higher in the control group but between group differences were not statistically significant (€2255 vs. €2780, *p*=.20)
Kuriyama et al, 2004[196] (JAPAN)	N=26,110 • 40 – 79 years • Japanese National Health Insurance (NHI) beneficiaries	• Prospective cohort with 7 years of follow-up • Osaka NHI Cohort • Examine the joint impact of modifiable health-risk factors on direct health care charges • Stratified into 8 categories based on the presence of three risk factors: smoking, obesity, physical inactivity and their combinations • Data on HCU and HCC obtained for the 7-yr study period	**Independent** • Self-reported average daily walking, grouped as: ≤30 min; 30-60 min; >60 min – Inactivity defined as <1 hr./day of walking **Dependent** Administrative claims HCU/HCC data • Average monthly charges calculated by dividing total charges accumulated in the study period by the number of months observed	• Physical inactivity was associated with 8.0% higher HCC than the 'no risk' group • Combined health risks were associated with higher HCC – Smoking/Inactivity=31.4% – Obesity/Inactivity=16.4% – All 3 health-risk factors=42.6%

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Leigh & Fries, 1992[173] (USA)	N=1558 • Bank of America retirees • Mean age = 68.5 yrs.	• Prospective • Examined association between health habits and costs in retirees • Health promotion intervention − lifestyle questionnaires at 6-month intervals − personal health risk reports, − individual recommendations − self-management workbook − quarterly newsletters • Intervention and control groups combined for analysis • Healthtrac data collected between Jan 1988 and Apr 1989	**Independent** • Self-reported weekly exercise (min/wk.) **Dependent** Self-reported HCU in last 6 months • hospital days • dr. visits • sick days at home Estimated high, low and medium direct and indirect costs	• Add'l 100 min/wk. of exercise reduces hospital days by 0.16 days and dr. visits by 0.16 visits
Liu-Ambrose et al, 2008[197] (CAN)	N=209 • Community dwelling older adults with chronic conditions • 65 yrs. & old	• Cross-sectional • HCU assessed with Health Resource Utilization Questionnaire • Costs calculated using perspective of British Columbia Ministry of Health	**Independent** • Self-reported PA (MET·hr/day) based on Physical Activity Scale for Individuals with Physical Disabilities **Dependent** • Self-reported direct HCU in the preceding 3 months Controlled for age, sex, number of chronic conditions, balance score, global cognitive function	• Current PA was independently and inversely associated with health resource utilization, explaining approximately 3.3% of the variance

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Martin et al, 2006[177] (USA)	N=1000 • Community dwelling • 65 yrs. & older • Random sample of Medicare beneficiaries from 5 counties in AL • Racially diverse, urban and rural	• Cross-sectional • 12-month time frame • University of Alabama (AL) Study of Aging (1999-2001)	**Independent** • Self-reported LTPA(kcal/week) based on modified Minnesota Leisure Time Activity Questionnaire **Dependent** • Self-reported HCU in the preceding 12 months − ER visit – yes/no − # of hospital admissions − # of nights in hospital − # of doctor visits Controlled for 12 covariates related to HCU	• LTPA did not predict # of physician visits, hospital stays, ER use • LTPA negatively associated with # of nights spent in hospital
Martinson et al, 2003[198] (USA)	N= 2,393 • 50 yrs. and older • Stratified random sample of 8000 members of a Minnesota health plan • 3 strata based on diagnosed CAD; diabetes; hypertension; dyslipidemia (ICD-9-CM) – 0/4 conditions – 1/4 conditions – 2+ conditions Excluded participants reporting any level of physical impairment at time of either survey	• Prospective cohort • Examined changes in PA and short-term HCC between two time periods (1994/95 and 1996/97) • Two surveys administered by mail approximately 12 months apart •	**Independent** • Change in self-reported PA status • Dichotomized PA level (active/inactive) based on the number of days they attained 30 min or more of PA in previous week. **Dependent** Difference in total health care claims/charges (1997 dollars) over 12 months. Conducted sensitivity analyses with five different operational definitions Controlled for 5 covariates (age, sex, chronic disease, smoking & BMI)	• Moving from inactive to active was associated with a significant decrease (~$2,200) in short term health care costs • Physically inactive older adults who are capable of increasing their PA should be strongly encouraged to do so.

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Munro et al, 2004[199] (UK)	N=6420 − n=2283 (intervention) − n=4137 (control) • Age 65 yrs. and older • In the least active • Intentional representation of women living in rural/remote areas	• Pragmatic, cluster randomized community intervention • 12 general practices in Sheffield UK − 4 practices randomly selected into intervention, 8 as control • Intervention groups were invited to attend locally organized, free, twice weekly 75-min exercise classes provided for up to 2 years • Data linkage with participants' health authority records • Analyzed using random effects multilevel models, adjusted for person-level covariates	**Independent** • Group: Intervention vs control **Dependent** Administrative HCU data • Hospital admissions Adjusted for: age, baseline PA score, sex, smoking, living arrangement, type of dwelling, and hospital admissions in two years prior to the study	• 26% of eligible study population attended one or more sessions in the 2 year study period • No differences in hospital admissions between intervention and control populations at the 2-year follow up
Nguyen et al, 2007[200] (USA)	N=163 • 65 yrs. and older • Health maintenance organization (HMO) enrollees on a diabetes registry (1998-2003) • Participated at least once in the EnhanceFitness (EF) physical activity benefit Age/sex matched comparison group (n=364)	• Retrospective matched cohort • Examined difference in HCC over 12-months and program effectiveness • HCC data from the HMO administrative decision support system	**Independent** • Participation in EF physical activity benefit (yes/no) **Dependent** • Change in HCC over 12-months − Inpatient hospitalization − Primary care visits − Diabetes related visits Covariates included age, sex, previous arthritis visits, heart disease and diabetes indicator, baseline HCC and HCU, prevention score	• Adjusted total HCC were not significantly different between groups • EF participants had higher primary care use (*p*<0.001) and costs (*p*<0.05) compared to controls • Those who attended EF 1 or more times per week had lower adjusted total HCC than controls (-$3.196; p<.05) and those attending less than once/week (-$3.714; p<.05).

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Nguyen et al, 2008[179] (USA)	N=4,766 • 65 yrs. and older • Health maintenance organization (HMO) enrollees (1997-2004) • Participated at least once in the plan-sponsored Silver Sneakers (SS) health club benefit Age/sex matched comparison group Participants excluded if: − <2ys continuous enrollment − missing cost data − long-term care costs at baseline	• Retrospective cohort • Examined whether the use of a health club benefit for older adults was associated with a reduction in total HCC • SS health club benefit provided access to local fitness centres in an unstructured format • HCU, HCC, demographic, and other covariates from the HMO administrative decision support system • Conducted sensitivity analyses using propensity score adjustments	**Independent** • Use of SS health club benefit − Any use in 2 yr. period (yes/no) − Average weekly frequency of use (<1 visit; 1to<2 visits; 2 to <3 visits; 3+ visits **Dependent** • Change in HCC over 2 years − Inpatient admissions − Primary care visits − Specialty care visits − Total health care costs Covariates included age, sex, health status, baseline HCC and HCU, patient risk, preventative services index, co-morbidity	• No difference in HCC between groups in Year 1 • In Year 2, SS participants had significantly fewer inpatient admissions (-2.3%, p=.001) and lower total HCC (-$500, p<.001) • Total HCC of SS participants averaging at least 2 health club visits/wk. over 2 years were $1252 (95% CI=-$1937 to -$567; p<.001) lower than those averaging less than one visit/wk.
Perkins & Clark, 2001[174] (USA)	N=655 • 55 yrs. & older • 5000 eligible participants identified from electronic medical records system • ≥ 1 scheduled visit to hospital-based outpatient general practice in previous 12-months • Sample list stratified based on age, sex and ethnicity 140 randomly selected from each strata	• Cross sectional • Regenstrief Physical Activity and Health Survey (RPAHS) − Survey with administrative healthcare data for 12-months • Face-to-face or telephone interview • Single question PA instrument modeled and piloted on the Physical Activity Scale for the Elderly (PASE) and the Yale Physical Activity Scale (YPAS) • HCU and HCC data from administrative medical records	**Independent** − Self-reported PA based on average weekly minutes of walking **Dependent** • HCU and HCC for 12-months following survey − primary care visits − ER visits − overnight hospitalizations − Health care costs based on total annual charges Controlled for sociodemographic characteristics, health status, chronic disease and health care utilization in the 12-months prior to the survey.	• 1-29 min of walking was associated with a lower risk of hospitalization − Those walking 1-29 min reported other PA minutes • >120 min of walking was associated with a lower risk of hospitalization and ER visits than those reporting no walking • Walking 30-119 min – no difference in risk

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Petrella et al, 1999[180] (CAN)	N=375 • Community dwelling adults aged 55-85 yrs. • Mean age = 68.5 yrs. • Stratified random sample • Stratification based on gender and age • Retired *n*=254; semi- or non-retired *n*=84	• Cross sectional • 12-month study period Individuals completed: − Questionnaires (demographics; PA habits; health care contacts) − Medical exam including ECG − Measured height/weight − Self-paced walking test − Treadmill test	**Independent** • Self-reported PA based on Minnesota Leisure Time Activity Questionnaire (MN-LTAQ) • Fitness measures including: strength, flexibility, aerobic power and sum of 4skinfolds **Dependent** • Primary care physician in the last 12 months – Dichotomous – yes/no	• 70% of respondents reported seeing a primary care physician in the past year; 46% of this group had seen their physician in the past month. • Non-significant bivariate association between PA and physician contact (*p*=.10) • Bivariate associations between fitness measures and physician contacts were non-significant, except for right plantar flexor strength (*p*=.01)
Plotnikoff et al, 2008[201] (CAN)	N=2,311 • Population-based • T1D & T2D individuals • T1D → 46.3% M; mean age=52.5 yrs. T2D → 51.4% M; mean age=63.8 yrs.	• Cross sectional • Alberta PA and Diabetes Research Advancement Study • Examined association between 3 health behaviours and HCU/HCC in T1D and T2D individuals • Demographic information, self-reported PA, diet and smoking data collected via survey • Respondents asked to consent to linkage with administrative health data (~54% consented) • Compared consenting and non-consenting to assess responder bias	**Independent** • Self-reported PA in the preceding month (Godin LTEQ) – Classified as active or inactive based upon achieving diabetic-specific weekly PA guidelines of 150 MVPA • Total PA (MET-minutes/wk.) also modeled **Dependent** • Linked administrative health data (for the year 2002) − # of general practitioner visits − # of general practitioner claims − # of hospital visits − total # of physician claims − total costs of physician claims Controlled for demographic (5), health (4) and other behaviours (2)	• No significant associations were found in primary (adjusted) analyses (Full regression model). • Subsidiary analyses (1-tailed t-tests) showed: – Inactive T2D respondents had significantly higher HCU and HCC, across all measures – Inactive T1D respondents had significantly higher # of general practitioner visits and # of general practitioner claims only • Findings suggest that: − achieving PA guidelines more important from a health care perspective for T2D individuals (compared to T1D) − simply expending energy (not necessarily meeting PA guidelines) may influence HCU/HCC in T1D/T2D persons • data linkage may be over-represented by healthy individuals (threat to internal validity)

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type & Data Source	Key variables	Principal Findings
Pronk et al, 1999[202] (USA)	N=5,689 • Stratified random sample (N=8000) • 40 years and older • Members of a Minnesota health plan • 3 strata based on diagnosed coronary artery disease; diabetes; hypertension; dyslipidemia – 0/4 conditions – 1/4 conditions – 2+ conditions	• Cohort study • 12-month study period • Examine the relationship of modifiable health risks to short-term HCC after controlling for age, race, sex and comorbidity • Billed HCC for 18-month period in 1995/96	**Independent** • Change in self-reported PA status • Dichotomized PA level (active/inactive) based on the number of days they attained 30 min or more of PA in previous week. **Dependent** • Difference in total health care claims/charges (1997 dollars) over 12 months. Controlled for 5 covariates (age, sex, chronic disease, smoking & BMI)	• Adjusted analyses showed that PA was associated with 4.7% lower HCC per active day per week
Sari, 2010[172] (CAN)	N=18,196 • Population-based • Multi-stage stratified cluster design • 65 yrs. & older	• Cross Sectional • 12-month study period • Canadian Community Health Survey (CCHS 2.1)	**Independent** • Self-reported leisure time PA − Total daily energy expenditure **Dependent** • Self-reported hospital services utilization in previous 12 months − Hospital admission − # of nights spent in hospital Controlled for: ≥ 25 predisposing, enabling and need factors	• Leisure time PA is negatively associated hospitalizations and with the # of hospital nights among users. • If inactive older adults increase PA by 20 min/day, # of nights could decrease by 16%-19%. • Total inpatient days could decrease by 2.7% which is equivalent to 1.7% of annual bed capacity in Canada
Smith et al, 2006[203] (USA)	N=113 • Community-dwelling • Men n=39;mean age=75.3yrs • Women n=74; mean age=76.5yrs	• Retrospective case series • Examined effects of an exercise-based comprehensive rehabilitation program • Individualized physical therapy with therapeutic exercises 3 times/week for 3 months	**Independent** • Baseline and 3-month time point **Dependent** • Self-reported medical events during previous 3-months – # of hospitalizations – # of physician visits	• Significant reductions in rate of hospitalization and physician visits during the 3-month intervention

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

Table 2.6 continued

Study	Sample Description	Study Type and Data Source	Key variables	Principal Findings
Wang et al, 2005[175] (USA)	N=42,520 • 65 yrs. & older • Retired General Motors employees and spouses Study included those who had selected insurance plan for 2001/02 and completed a health risk appraisal during this period	• Cross-sectional • Examine the influence of PA and BMI on HCU and HCC among Medicare retirees • PA and BMI data collected through at the health risk appraisal • Claims data from Medicare and indemnity insurance plans • Stratified into groups based on BMI, PA and age	**Independent** • Self-reported PA based on single question. Classified into 3 levels: sedentary, moderately active and very active **Dependent** • Annual health service use – outpatient claims – ER visits – hospitalization days • Annual health care costs – outpatient costs – inpatient costs – drug costs Controlled for gender, age, health risk, major diseases, chronic disease and BMI	Compared to sedentary group, active and moderately active older adults had: • Lower numbers of outpatient claims*, ER claims & hospital days • lower inpatient, outpatient, drug costs than sedentary group • Active group had significantly lower numbers of outpatient claims, ER claims and lower costs than moderately active • *except for the number of outpatient claims in the obese category
Woolcott et al, 2010[182] (CAN)	N=24,281 • Population-based • Multi-stage stratified cluster design • 65 yrs. & older	• Cross-sectional • 12-month study period • Canadian Community Health Survey (CCHS 1.1) • Costs estimated based on BC Ministry of Health Medical Services fees/benefits	**Independent** • Self-reported LTPA (kcal/week) **Dependent** • Self-reported HCU in the preceding 12-months − Hospital admission – yes/no − # of visits to physicians & health professionals • Estimated total health care costs Controlled for: age, sex, body weight, chronic conditions, health related quality of life and marital status	• Inactive respondents at elevated risk of hospitalization compared to active respondents (OR_{adj}=1.84). • Costs associated with health resource use were significantly higher for inactive individuals compared to active counterparts • Costs decreased with increasing activity

Legend: Health maintenance organization (HMO); Lifetime Fitness Program (LFP); Health care costs (HCC); Health care utilization (HCU); EnhanceFitness (EF); physical activity (PA); body mass index (BMI); health services utilization (HSU); randomized control trial (RCT); aerobic training (AT); resistance training (RT); intervention group (IG); control group (CG); activities of daily living (ADL); emergency room (ER); Type I Diabetes (T1D); Type II Diabetes (T2D)

2.3.2.1 Physical Activity and Use of Physician Services

In Canada, primary care physicians [also known as general practitioners (GP)] are often the initial point of contact with the health care system for individuals with new health concerns as well as the primary contact for those needing preventative check-ups and/or care for ongoing health concerns. These physicians also act as the primary gatekeepers to specialist services. Approximately 72% of Canadians under the age of 65 years and 76% of those 65 years and older report visiting a GP at least once per year, with the proportion increasing with increasing comorbidity and the perception of fair or poor general and mental health.[28]

Canadian studies of PA and the use of physician services have reported equivocal findings, with some reporting no relationship while others report a significant inverse relationship. Petrella et al (1999)[180] examined bivariate associations between self-reported contact with a primary care physician and four measures of physical fitness along with self-reported PA in a sample of 375 community-dwelling older adults aged 55 and 84 years of age. Neither physical fitness nor self-reported PA were significantly associated with physician contact in the previous 12-months, a finding that the authors acknowledged was unexpected and which they attributed to the high relative health status and physical fitness of the sample.[180] In this study, physician contact was measured with a dichotomous variable indicating contact or no contact. It is possible that this operationalization of the dependent variable was too crude, opening up the possibility of type I error. Perhaps a more nuanced measured of physician contacts, such variable counting the number of contacts, would have uncovered the hypothesized association. Another possibility is that with its small sample size, this study lacked the statistical power necessary to reveal a significant association.

More recently, Plotnikoff and colleagues (2008)[201] examined the association between PA and other health behaviours and health services utilization and costs in a population-based cohort of 2,311 individuals with type 1 (T1D) and type 2 diabetes (T2D). Although this sample was not limited to older adults, the mean age of T1D and T2D participants was 52.5 ±11.6 years and 63.8±11.6 years, respectively. Participants completed a questionnaire assessing demographics and health determinants, including leisure time physical activity (LTPA). Physical activity was assessed in two ways: a continuous measure of LTPA in MET·min/wk and a categorical variable classifying respondents as 'active' or 'inactive' based upon achieving diabetes-specific guidelines of 150 minutes of moderate to vigorous PA (MVPA) per week. Health services utilization and cost information was obtained for consenting participants (n=1,025) through the linkage of their data with the provincial Ministry of Health administrative database.[201] In multiple regression analyses adjusted for other behavioral factors (smoking and diet), LTPA was negatively associated with the GP visits, GP claims and total physician claims (GP and specialist); however among T2D participants the association was only significant for total physician claims. When demographic and health factors were also included in the models, LTPA was not significantly associated with any measures of physician services utilization. Subsidiary bivariate analyses undertaken to determine if those achieving diabetes-specific PA guidelines had greater HSU showed that inactive T1D participants had significantly more GP visits and claims than their active counterparts while T2D participants had significantly more GP visits and claims, as well as total physician claims.[201] While this study has the advantage of data linkage with individual participant's administrative health records, the low consent rate (~54%) significantly limited the sample size available for analysis, raising concerns of responder bias, which were confirmed in subsequent analyses.[201] As a result of these concerns as well as inconsistency in the reported findings, the authors acknowledge that they are unable to draw solid conclusions based on their results.[201]

A third Canadian study examining the association between PA and health services utilization and costs was published in 2010. Using data from Cycle 1 of the Canadian Community Health Survey, Woolcott and colleagues (2010)[182] compared 'general health visits' between active and inactive respondents in a nationally representative sample of 24,281 older adults aged 65 years and older. General health visits, in this case, were not limited to visits to general practitioners and specialist physicians but also included visits to other health care providers such as physiotherapists, optometrists, chiropractors, and psychologists. Leisure-time PA was dichotomized based on estimated weekly energy expenditure where participants expending less than 1000 kcal/wk were deemed inactive. Bivariate comparisons showed that physically active seniors had significantly fewer 'general health visits' than their inactive counterparts (8.15 vs. 11.76 visits/yr). This analysis was not adjusted for potential confounders; therefore, it is possible that this difference can be partly explained by unmeasured differences between the two groups, a limitation that is shared by the two previous studies as well.[182]

Only one study was found that examined specialist visits separate from GP visits. Using data from the 1994 National Population Health Study, Dunlop et al (2000)[181] examined the relationship between socioeconomic status and use of general and specialist physician services in Canadian adults.[181] Although not a primary research finding, they reported that physical inactivity was associated with the number of visits to specialist physicians but not general physicians. The association between PA and specialist visits differed by sex and the way in which the variable was operationalized. When examining use (≥ 1 visit) versus non-use (no visits) of specialist services, moderately active and inactive males were 6% and 20% more likely than active males, respectively, to have used specialist services in the previous year; however, among females, these associations were not significant. When high (≥ 6 visits) and low use (< 6 visits) of specialist services was examined, significant associations between physical inactivity and high use of specialist services were seen in females but not males, with moderately active females being 13% less likely and inactive females 32% more likely than active females to be high users of specialist visits.[181] In comparison to the previously discussed studies, this study included a broad range of control variables (14 variables in total) in the analysis; however, the study population included Canadians 12 years of age and older, thus limiting its generalizability to the older adult population.

2.3.2.2 Physical Activity and Use of Hospital Services

The largest proportion of public-sector health care funding (37.3%) is directed to hospitals.[30] The most commonly used measure of hospital services utilization is the number of hospitalizations. Length of stay, referring to the number of hospital days within a given hospitalization, is another measure of utilization. Some data sources (for example, the Canadian Community Health Survey) use the total number of days spent in hospital in a given time period, which may or may not be reflective of the length of stay, depending on the number of hospitalizations during the period considered.

Older adults use a disproportionate amount of hospital services, compared to other age groups. In 2009/2010, seniors accounted for 40% of acute hospital stays in Canada, despite comprising just 14% of the population.[30] They also use hospitals in different ways. For example, seniors stay longer in emergency departments and acute care settings while younger adults stay longer in inpatient rehabilitation and complex continuing care.[30]

Three of eight Canadian studies of PA and health services utilization and costs examined the use of hospital services and, similar to the literature related to physician services, no clear consensus has emerged. In their study of T1D and T2D diabetic adults, Plotnikoff et al (2008)[201] reported that T2D participants not achieving recommended levels of PA had significantly more hospital visits than those who did meet the guidelines; however in the adjusted analyses, PA was not significantly associated with the number of hospital visits. No significant associations between either PA measure and hospital visits were found in T1D participants.[201]

Woolcott et al (2010)[182] compared the odds of being hospitalized between active and inactive seniors in the CCHS Cycle 1 sample. Adjusted analyses showed that physically inactive individuals were 84% more likely to be hospitalized in the previous 12 months than their active counterparts. Inactive respondents also spent significantly more days per year in hospital than their active counterparts (3.18 vs. 0.82 days; $p<.01$).[182] Another study published in 2010 also used data from the CCHS (Cycle 2) to examine the association between LTPA and the demand for hospital services in Canadian seniors.[172] In this study, Sari (2010) reported that a small increase in LTPA could translate into 16% to 19% fewer annual hospital days among inactive older adults. He further estimated that an additional 20-minute walk daily walk by all inactive seniors would decrease hospital days by approximately 392,000 days per year, which corresponds to 2% of total annual inpatient days or 1.2% of hospital bed capacity.[172]

Of all the Canadian studies, these last two are perhaps the most easily compared, given that they share common dependent variables and similar study populations. The study by Sari (2010)[172] provides strong support for the findings of Woolcott et al (2010)[182], particularly because of the different analytical approach used. Although both studies controlled for other predictors of hospital services utilization, the set of control variables included in Sari's analysis was far more comprehensive than that used by Woolcott et al (2010), thus reducing the potential for bias associated with unobserved predictors of hospital services utilization. Furthermore, instead of treating the dependent variable (number of days spent in hospital in the previous 12-months) as a continuous variable, Sari (2010) used a statistical approach specific to count data outcomes.[172] Approaches specific to count data better account for the distributional properties of health services utilization data and thus, protect against bias and produce more robust estimates.[165,204]

2.3.2.3 Physical Activity and Healthcare Costs

Physical activity is thought to have a role to play in reducing both direct and indirect healthcare costs. Direct costs are those associated the provision of healthcare services, including diagnosis, treatment, prevention and management costs. Indirect costs refer to the foregone opportunities and resources associated with health conditions, including lost productivity, disability, and pre-mature mortality. As previously discussed, the direct, indirect and total costs (in 2009 dollars) of physical inactivity have been estimated to be $2.4 billion, $4.3 billion, and $6.8 billion, respectively.[169] In contrast to measures of utilization, there is no 'gold standard' for estimating healthcare costs, which can make comparisons between studies difficult.[197] However, unlike the utilization measures, associations between PA and healthcare costs in older adults are more consistently reported.[182,197,201]

Recently, Liu-Ambrose et al (2010)[197] published a study examining the association of PA and direct healthcare costs in 209 community-dwelling older adults with multiple chronic conditions. Health resource utilization was assessed using a researcher-administered questionnaire designed for older adults with cardiovascular disease and/or arthritis to capture resources used in the previous 3 months. Direct costs were then calculated using cost schedules outlined by the provincial Ministry of Health. Self-reported PA was assessed using a 13-item questionnaire that provides a PA score based upon metabolic demands in three domains – recreation, household and occupational activities. After adjusting for age, sex, number of chronic conditions, general balance and mobility and cognitive function, PA was found to make a small but significant contribution, accounting for approximately 3.3% of the variance in direct healthcare costs. However, the full model itself explained just 27.6% of the variance in direct healthcare costs, indicating a sizeable degree of unexplained variance.[197]

In their previously described study of T1D and T2D older adults, Plotnikoff and colleagues (2008)[201] also examined the association of PA and combined costs associated with GP and specialist physician claims. In regression analyses adjusted for other behavioral factors (smoking and diet), LTPA was significantly negatively associated with physician costs in T2D participants only. When demographic and health factors were also included in the model, the association between LTPA and physician costs was no longer significant. The subsidiary analyses showed that T2D participants who did not achieve recommended levels of PA had significantly higher physician costs than their more active counterparts.[201]

Woolcott and colleagues[182] also showed a significant negative association between PA and healthcare costs in their large, nationally representative sample of Canadian seniors. In this study, total costs of health resource use were determined by applying unit cost estimates from the British Columbia Ministry of Health to the participants self-reported utilization data. Physically active participants had significantly lower annual costs related to health visits ($331 vs. $452, $p<.01$) and hospital costs ($464 vs. $1795; $p<.01$). In extrapolating these costs, Woolcott et al (2010) estimate that inactive seniors have annual health resources costs in excess of $5.6 billion dollars.[182] A secondary analysis was undertaken to explore a potential dose-response relationship. In this analysis, participants were stratified into 5 levels (0-499; 500-999; 1000-1499; 1500-1999; >2000 kcal/week) based on the self-reported PA level and the total costs of health resource use were estimated and compared across groups. The results showed that healthcare costs decreased as PA level increased, except for a non-statistically significant increase between those expending 1500 to < 2000 kcals/week and those expending more than 2000 kcals/week.[182]

Although these studies provide evidence that PA leads to lower costs associated with health services utilization, caution should be exercised in interpreting these findings. In two of the three studies, costs were based on self-reported utilization, which are likely to be considerably less precise than those obtained through administrative databases.[197] Furthermore, the cost estimates in these studies likely suffer from a certain level of bias, given that they are based on unadjusted or minimally adjusted analyses.[165]

2.3.2.4 Physical activity interventions and health services utilization

To date, less than a handful of Canadian studies have examined the impact of a PA intervention, or change in PA levels, in community-dwelling older adults on subsequent healthcare utilization and/or healthcare costs. Recently, Davis et al published a series of economic evaluations of exercise interventions aimed at falls prevention[189,190] and executive cognitive function[191] in which healthcare resource costs were determined based on self-reported health professional visits, hospital visits and admissions, and laboratory and diagnostic tests. The earliest of these studies determined the cost-effectiveness and cost-utility ratio of a 12-month randomized control trial (RCT) of resistance training in 155 women aged 65 to 75 years. Participants were randomized to one of three groups: once-weekly or twice-weekly high intensity resistance training intervention or a twice-weekly balance and toning control group. All classes (resistance training and balance/toning) were 60 minutes in duration, with a 10-min warm-up, 40-min exercise component and a 10-min cool down period. Questionnaires were used to track healthcare resource utilization data at 3-month time intervals for 9 months of the 12-month study period. The major categories of utilization were visits to healthcare professionals, hospital visits and admissions, and laboratory and diagnostic tests, with costs assigned based on Ministry of Health fee for service rates, compensation information published by various provincial professional associations and cost models for a tertiary care hospital. In this study, mean total healthcare costs were found to be lower among participants in the two resistance training intervention groups compared to the wellness-based, balance and toning control group.[189] A follow-up study examining the sustained effects of this intervention subsequently reported that the mean total healthcare costs remained lower in the intervention groups compared to the control group in the 12 months following the cessation of the intervention even though the health benefits obtained in the trial were not sustained.[190] In 2013, Davis et al published a similar study of a 6-month RCT of resistance and aerobic training for community-dwelling women reporting mild cognitive impairments.[191] In this study, participants were randomized to a twice-weekly, class-based resistance training program, a twice-weekly, class-based aerobic training (outdoor walking) program or a twice-weekly balance and toning control group. Mean total healthcare costs over the 6-months were lower in both the resistance training and the aerobic training groups compared to a balance and toning exercise control group; however, mean costs for health professional visits and hospital admissions were higher in the resistance training group compared to the aerobic training group.[191] These studies are among a very limited number of prospective studies of the effects of physical activity/exercise on health services utilization and costs, and they share a number of strengths and limitations. The frequent (every 3 months) collection of self-reported health services utilization data to minimize recall bias and the use of multiple imputation and bootstrapping to estimate the uncertainty resulting from missing values and small sample size are important strengths of these studies.[189-191] However, the relatively short time frame of these studies (6 to 21 months) limits the conclusions that can be drawn regarding the longer term benefits of physical activity on health services utilization and costs.

Given the paucity of Canadian studies examining the effects of physical activity interventions on health services utilization and healthcare costs in older adults, a summary of the evidence from intervention studies in other countries is also provided. Buchner et al (1997)[186] randomized 181 seniors to one of three supervised training groups (aerobic training, strength training, or both) or to a non-exercise control group. The intervention consisted of supervised exercise (1-h sessions, three per week, for 24-26 weeks), followed by self-supervised exercise. Outpatient visits and the use of hospital services were compared between the 12-months prior to the intervention and the 12-months after the intervention. Outpatient visits remained stable over time in the exercise groups but increased in the control group. However, there were no differences between the groups in outpatient costs. Hospital use following intervention was similar between exercise and control groups, however control participants were more likely to spend more than 3 days in hospital ($p<.05$) and were more likely to have >$5000 in hospital costs.[186]

In a retrospective cohort study Nguyen et al (2007)[200] compared changes in healthcare costs between a group of diabetic health maintenance organization (HMO) enrollees who participated in a PA benefit with a group of age and sex matched controls. The program, EnhanceFitness, was a supervised, group-based exercise program designed to increase health and functional ability in sedentary, community-dwelling older adults. The supervised, instructor-led classes were offered three times per week at multiple community-based sites and followed a set format that included a 5-minute warm-up period, 20-25 minutes of moderate-intensity aerobics, 20-minutes of resistance strength training and 10 minutes of flexibility and balance training. Adjusted analyses showed that over a 12-month period, diabetic program participants had higher primary care use and costs compared to their control counterparts while total annual health care costs were similar between the two groups. Diabetic participants whose attendance at the EnhanceFitness program averaged at least once per week had, on average, 41% lower healthcare costs compared to participants whose attendance averaged less than once per week.[200]

In a follow-up study to Nguyen et al (2007)[200], Ackermann and colleagues (2008) compared changes in healthcare costs over a 2-year period between a cohort of HMO enrollees who participated in the EnhanceFitness PA benefit with a group of age and sex matched controls.[184] In the first year of the program, healthcare costs were similar between the participant and control groups but by the second year, adjusted total costs were significantly lower among program participants compared to controls. In the 12-months after first attending EnhanceFitness, program participants had a lower hospitalization rate but more primary care visits and higher primary care costs than controls; total and specialty care costs in this period were not significantly different between groups.[184] During the second year (13–24 months after first attending), program participants still had higher primary care costs than controls, but they had significantly lower inpatient and total healthcare costs.[184] In a similar study examining a separate program (Silver Sneakers), Nguyen et al (2008)[179] found that in the first year, adjusted total health care costs did not differ between Silver Sneakers participants and controls but by the second year, Silver Sneakers participants had approximately 2.5% fewer inpatient admissions and total healthcare costs that were approximately $500 lower than their control counterparts.

Furthermore, program participants averaging at least 2 class per week had significantly lower total healthcare costs compared to those averaging less than 1 class per week.[179]

In 2008, Chen et al used a prospective controlled trial to evaluate the effects of a 12-week walking program on health service utilization in community-dwelling older adults in Taiwan.[187] Random sampling was used to identify four experimental and four control communities, following which 1,175 prospective participants were systematically sampled. Of the 161 older adults who responded, just 96 individuals met the inclusion criteria and were willing to participate.[187] The 12-week walking intervention included three hospital-based, nurse-led walking sessions per week. After a 10 to 15 minute warm-up, participants were asked to walk for 20 to 30 minutes on a treadmill at a rating of perceived exertion (RPE) of 10 to 12 which was followed by a 10-minute cool-down period. Self-reported health service utilization measures included the number of hospitalizations, outpatient department or clinic visits, and emergency visits in the preceding 3-months. There were no significant differences between the walking and control groups in pre- and post- intervention changes in outpatient visits; however, the number of outpatient visits increased significantly in the control group while in the walking group, there was no significant change in outpatient visits.[187] The authors also conducted a cost-utility analysis to confirm the cost-effectiveness of the program, concluding that the program was worth promoting.[187]

While not intervention studies per se, both Martinson et al (2003)[198] and Jacobs et al (2013)[194] examined the impact of changes in PA on health services costs and/or utilization. Martinson et al (2003) assessed the impact of changes in self-reported PA in one year on short-term changes in healthcare costs in a stratified random sample of community dwelling adults aged 50 years and older.[198] After adjusting for age, gender, comorbidity, smoking status and

BMI, the results showed that annual healthcare costs declined by more than $2,000 among those who increased their PA from 0–1 days/week to three or more days/week[198]. Jacobs and colleagues (2013) examined changes in self-report PA levels, ER visits and hospitalization between ages 78 and 85 in a representative sample of 2,069 older adults from the Jerusalem Longitudinal Cohort Study.[194] Their results showed that after adjusting for sex, education, psychosocial factors, comorbidity, self-rated health, BMI and smoking, respondents who initiated PA between the age 78 and 85 did not differ from those who were consistently active in ER visits or hospital admissions while ceasing PA and never being active between age 78 and 85 were associated with increased ER visits and hospitalization.[194]

Lastly, in the Senior Fitness and Prevention (SEFIP) Study, Kemmler et al (2010) examined the effects of a weekly program consisting of two 60-minute class-based and two 20-minute home-based exercise sessions on fracture risk, CHD risk factors and healthcare costs in community-dwelling women 65 years and older.[195] The supervised group classes included aerobic activity, static and dynamic balance training, functional gymnastics, resistance training and stretching exercises while the home-based training emphasized strength and flexibility exercises which were modified every 12 weeks.[195] Participants randomized to the control group participated in a low intensity, intermittent wellness-based program for 10 weeks followed by 10 weeks of no programming in repeated cycles for the length of the intervention. Total healthcare costs were obtained from insurance-based administrative data for the 6-months prior to the study onset and the entire 18-month intervention period. The results showed that the mean direct healthcare costs over 18-months were approximately $500 lower in the exercise group compared to the control group; however, this was not statistically significant.[195] The authors suggested that this may be due to unintended positive effects of the control program on the primary study endpoints, which is an important limitation of this study. Another possibility was that the study population, overall, was healthier than average given that the total healthcare costs for the study cohort were well below the average costs for German women 65 to 80 years of age.[195]

While the literature summarized above provides general support for the potential of PA as a potential target for strategies aimed at reducing health care utilization and containment of health care costs, wide variations in sample sizes, in study designs, and in the nature of interventions, as well as the lack of Canadian data make firm generalizations problematic.[165] At a minimum, consensus among researchers and policymakers as to the “gold-standard” measures of health services utilization and healthcare costs would facilitate comparisons between studies and would allow for greater clarity in regards to the relationship between PA and health services utilization, in general.[197] Moreover, there remain significant gaps in the literature pertaining to PA and health services utilization, especially in the Canadian older adult population.[165] There is a clear need for further research, particularly prospective and/or longitudinal studies, in order to better understand the potential impact of PA on health services utilization and healthcare costs in an aging Canadian population. This evidence may then be used to better inform and evaluate strategies to increase PA participation among older Canadians, thus increasing the potential of these strategies to have a long-term, sustainable impact on the healthcare system.

2.4 LITERATURE CITED

1. Kalache A, Keller I. The WHO perspective on active ageing. *Promotion & Education.* 1999;6(4):20-23.
2. Spirduso WW, Francis KL, MacRae PG. Physical function of older adults. In: Spirduso WW, ed. *Physical Dimensions of Aging.* 2nd ed. Champaign, IL: Human Kinetics; 2005:261-286.
3. Sander M, Avlund K, Lauritzen M, Gottlieb T, Halliwell B, Stevnsner T, Wewer U, Bohr VA. Aging—From molecules to populations. *Mechanisms of Ageing and Development.* 2008;129(10):614-623.
4. Stein C, Moritz C, WHO's Ageing and Health. *A Life Course Perspective of Maintaining Independence in Older Age.* Geneva: World Health Organization; 1999.
5. World Health Organization. *A Life Course Approach to Health.* Geneva: World Health Organization; 2000.
6. Gilmour H, Park J. Dependancy, chronic conditions and pain in seniors. *Health Reports.* 2006;16(Suppl):21-31.
7. Chief Public Health Officer of Canada. *Report on the State of Public Health in Canada, 2010: Growing older - Adding life to years.* Ottawa, ON: Government of Canada; 2010.
8. World Health Organization Noncommunicable Diseases and Mental Health Cluster, Noncommunicable Disease Prevention and Health Promotion Department, Ageing and Life Course. *Active Ageing: A Policy Framework.* Geneva: World Health Organization; 2002.
9. Vahia IV, Thompson WK, Depp CA, Allison M, Jeste DV. Developing a dimensional model for successful cognitive and emotional aging. *International Psychogeriatrics.* 2012;24(04):515-523.
10. Depp CA, Jeste DV. Definitions and predictors of successful aging: A comprehensive review of larger quantitative studies. *American Journal of Geriatric Psychiatry.* 2006;14:6-20.
11. Rowe JW, Kahn RL. Human aging: Usual and successful. *Science.* 1987;237:143-149.
12. Nusselder WJ, Peeters A. Successful aging: Measuring the years lived with functional loss. *Journal of Epidemiology and Community Health.* 2006;60:448-455.
13. Rowe JW, Kahn RL. Successful aging and disease prevention. *Advances in Renal Replacement Therapy.* 2000;7(1):70-77.
14. Topp R, Fahlman M, Boardley D. Healthy aging: Health promotion and disease prevention. *Nursing Clinics of North America.* 2004;39:411-422.
15. Schulz R, Heckhausen J. A life span model of successful aging. *American Psychologist.* 1996;51(7):702-714.

16. von Faber M, Bootsma–van der Wiel A, van Exel E, Gussekloo J, Lagaay AM, von Dongen E, Knook DL, van der Geest S, Westendorp RG. Successful aging in the oldest old: Who can be characterized as successfully aged? *Archives of Internal Medicine.* 2001;161(22):2694-2700.

17. Fries JF. Successful aging - An emerging paradigm of gerontology. *Clinics in Geriatric Medicine.* 2002;18(3):371-382.

18. National Seniors Council. *Report of the National Seniors Council on Volunteering Among Seniors and Positive and Active Aging.* Ottawa, ON: Government of Canada; 2010.

19. Dalgren G, Whitehead M. *Policies and Strategies to Promote Social Equity in Health.* Stockholm: Institutes for Futures Studies; 1991.

20. Whitehead M, Dahlgren G, Gilson L. Developing the policy response to inequities in health: a global perspective. *Challenging Inequities in Health: From Ethics to Action.* 2001:314-315.

21. Martel L, Belanger A, Berthelot J-M, Carriere Y. Healthy Aging. In: *Healthy today, Healthy tomorrow? Findings from the National Population Health Survey*. Ottawa, ON: Statistics Canada; 2005.

22. Ramage-Morin PL, Shields M, Martel L. Health-promoting factors and good health among Canadians in mid- to late life. *Health Reports.* 2010;21(3):45-53.

23. Turcotte M, Schellenberg G. *A Portrait of Seniors in Canada*. Ottawa, ON: Statistics Canada; 2007.

24. Statistics Canada. *Leading Causes of Death in Canada*, 2009. Ottawa, ON: Statistics Canada; 2012.

25. Statistics Canada. *Canada Year Book 2012*. Ottawa: Statistics Canada; 2012.

26. Public Health Agency of Canada. The facts: Seniors and injury in Canada. *The Safe Living Guide - A guide to home safety for seniors*. Ottawa, ON: Public Health Agency of Canada; 2011.

27. Statistics Canada. *Healthy People, Healthy Places*. Ottawa, ON: Statistics Canada; 2010.

28. Nabalamba A, Miller WJ. Going to the doctor. *Health Reports.* 2007;18(1):23-35.

29. Park J. Use of alternative health care. *Health Reports.* 2005;16(2):39-42.

30. Canadian Institute for Health Information. *Health Care in Canada, 2011: A Focus on Seniors and Aging*. Ottawa, ON;2011.

31. Edwards P, Mawani A. *Healthy Aging in Canada: A new vision, a vital investment from evidence to action. A background paper prepared for Federal, Provincial and Territorial Committee of Officials (Seniors)*. Ottawa, ON: Government of Canada; 2006.

32. Paterson DH, Jones GR, Rice CL. Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Canadian Journal of Public Health.* 2007;98 Suppl 2:S69-108.

33. Kirkwood TBL. Understanding the odd science of aging. *Cell.* 2005;120(4):437-447.

34. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. *The Lancet.* 381:752-762.

35. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie MA. Frailty in Older Adults: Evidence for a Phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2001;56(3):M146-M157.

36. Barzilay JI, Stein PK. Association of the metabolic syndrome with age-related, nonatherosclerotic, chronic medical conditions. *Metabolic Syndrome and Related Disorders.* 2011;9(5):327.

37. Lang PO, Michel JP, Zekry D. Frailty Syndrome: A transitional state in a dynamic process. *Gerontology*. 2009;55(5):539-549.

38. United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council of Physical Fitness and Sport. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: United States Department of Health and Human Services; 1996.

39. Paterson D, Warburton D. Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):38.

40. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: The evidence. *Canadian Medical Association Journal.* 2006;174(6):801-809.

41. North BJ, Sinclair DA. The intersection between aging and cardiovascular disease. *Circulation Research.* 2012;110(8):1097-1108.

42. Webb RC, Inscho EW. Age-related changes in the cardiovascular system. In: LM P, ed. *Hypertension in the Elderly*. New York: Springer-Verlag 2010.

43. Parker BA, Kalasky MJ, Proctor DN. Evidence for sex differences in cardiovascular aging and adaptive responses to physical activity. *European Journal of Applied Physiology.* 2010;110(2):235-246.

44. Fleg JL, J S. Age-associated changes in cardiovascular structure and function: A fertile milieu for future disease. *Heart Fail Rev.* 2012;17:545-554.

45. Strait JB, Lakatta EG. Aging-associated cardiovascular changes and their relationship to heart failure. *Heart Failure Clinics.* 2012;8(1):143-164.

46. Lee S-JL, Park S-H. Arterial ageing. *Korean Circulation Journal.* 2013;43:73-79.

47. Lakatta EG., Levy D. Arterial and cardiac aging: Major shareholders in cardiovascular disease enterprises. *Circulation.* 2003;107:346-354.

48. Hotta H, Uchida S. Aging of the autonomic nervous system and possible improvements in autonomic activity using somatic afferent stimulation. *Geriatrics & Gerontology International.* 2010;10:S127-S136.

49. Shephard RJ. Maximal oxygen intake and independence in old age. *British Journal of Sports Medicine.* May 1, 2009 2009;43(5):342-346.

50. Sung MY, Dyck JB. Age-related cardiovascular disease and the beneficial effects of calorie restriction. *Heart Fail Rev.* 2012/09/01 2012;17(4-5):707-719.

51. Lakatta EG. Age-associated cardiovascular changes in health: Impact on cardiovascular disease in older persons. *Heart Fail Rev.* 2002;7(1):1480.

52. Public Health Agency of Canada. Tracking Heart Disease & Stroke in Canada. Ottawa, ON: Government of Canada; 2009.

53. Vuori I. Exercise and physical health: Musculoskeletal health and functional capabilities. *Research Quarterly for Exercise and Sport.* 1995;66(4):276-285.

54. Mobasheri A, Mendes AF. Physiology and pathophysiology of musculoskeletal aging: Current research trends and future priorities. *Frontiers in Physiology.* 2013;4:1-2.

55. Anderson AS, Loeser RF. Why is osteoarthritis and age-related disease? *Best Practice & Research Clinical Rheumatology.* 2010;24:15-26.

56. Loeser Jr RF, Delbono O. Chapter 112. Aging of the Muscles and Joints,. In: Halter JB, Ouslander JG, Tinetti ME, Studenski S, High KP, Asthana S, eds. *Hazzard's Geriatric Medicine and Gerontology*. 6th Edition ed. New York: McGraw-Hill; 2009.

57. Mirolla M. *The Cost of Chronic Disease in Canada.* Nova Scotia: GPI Atlantic;2004.

58. Mitchell WK, Atherton PJ, Williams J, Larvin M, Lund JN, Narici M. Sarcopenia, dynapenia and the impact of advancing age on human skeletal muscle size and strength: A quantitative review. *Frontiers in Physiology.* 2012;260.

59. Degens H, Korhonen MT. Factors contributing to the variability in muscle ageing. *Maturitas.* 2012;73(3):197-201.

60. Berger MJ, Doherty TJ. Sarcopenia: Prevalence, mechanisms, and functional consequences. In: Mobbs CV, Hof PR, eds. *Body Composition and Aging*. New York: Karger; 2010.

61. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, Abellan van Kan G, Andrieu S, Bauer J, Breuille D, Cederholm T, Chandler J, De Meynard C, Donini L, Harris T, Kannt A, Keime Guibert F, Onder G, Papanicolaou D, Rolland Y, Rooks D, Sieber C, Souhami E, Verlaan S, Zamboni M. Sarcopenia: An undiagnosed condition in older adults. Current consensus definition: Prevalence, etiology, and consequences. *Journal of the American Medical Directors Association.* 2011;12(4):249-256.

62. Gielen E, Verschueren S, O’Neill TW, Pyr SR, O'Connell MD, Lee DM, Ravindrarajah R, Claessens F, Laurent M, Milisen K, Tournoy J, Dejaeger M, Wu FC, Vanderschueren D, Boonen S. Musculoskeletal frailty: A geriatric syndrome at the core of fracture occurrence in older age. *Calcified Tissue International.* 2012;91(3):161-177.

63. Kamel HK. Sarcopenia and aging. *Nutrition Reviews.* 2003;61(5):157-167.

64. Muscaritoli M, Anker SD, Argilés J, Aversa Z, Bauer JM, Biolo G, Boirie Y, Bosaeus I, Cederholm T, Costelli P, Fearon KC, Laviano A, Maggio M, Rossi Fanelli F, Schneider SM, Schols A, Sieber CC. Consensus definition of sarcopenia, cachexia and pre-cachexia: Joint document elaborated by Special Interest Groups (SIG) “cachexia-anorexia

in chronic wasting diseases” and “nutrition in geriatrics”. *Clinical Nutrition.* 2010;29(2):154-159.

65. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinková E, Vandewoude M, Zamboni M. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and Ageing.* 2010;39(4):412-423.

66. Walston JD. Sarcopenia in older adults. *Current Opinion in Rheumatology.* 2012;24(6): 623-627.

67. Janssen I, Baumgartner RN, Ross R, Rosenberg IH, Roubenoff R. Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. *American Journal of Epidemiology.* 2004;159(4):413-421.

68. Janssen I, Shepard DS, Katzmarzyk PT, Roubenoff R. The healthcare costs of sarcopenia in the United States. *Journal of the American Geriatrics Society.* 2004;52(1):80-85.

69. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bulletin of the World Health Organization.* 2003;81(9):646-656.

70. Suri P, Morgenroth DC, Hunter DJ. Epidemiology of osteoarthritis and associated comorbidities. *PM&R.* 2012;4(5, Supplement):S10-S19.

71. Felson DT. An update on the pathogenesis and epidemiology of osteoarthritis. *Radiologic Clinics of North America.* 2004;42(1):1-9.

72. Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, Jordan JM, Kington RS, Lane NE, Nevitt MC, Zhang Y, Sowers M, McAlindon T, Spector TD, Poole AR, Yanovski SZ, Ateshian G, Sharma L, Buckwalter JA, Brandt KD, Fries JF. Osteoarthritis: New insights. Part 1: The disease and its risk factors. *Annals of Internal Medicine.* 2000;133(8):635-646.

73. Lagace C, O'Donnell S, Diener A, Roberge H, Tanguay S. Chapter 6: Economic burden of arthritis. In: Public Health Agency of Canada, Arthritis Consumer Experts, Arthritis Community Research & Evaluation Unit, et al., eds. *Life with Arthritis in Canada, 2010*. Ottawa, ON: Public Health Agency of Canada; 2010.

74. Bombardier C, Hawker G, Mosher D. *The Impact of Arthritis in Canada: Today and over the next 30 years*. Toronto, ON: Arthritis Alliance of Canada; 2011.

75. Garriguet D. Bone health: Osteoporosis, calcium and vitamin D. *Health Reports.* 2011;22(3).

76. Demontiero O, Vidal C, Duque G. Aging and bone loss: New insights for the clinician. *Therapeutic Advances in Musculoskeletal Disease.* 2012;4(2):61-76.

77. Chen H, Zhou X, Fujita H, Onozuka M, Kubo K-Y. Age-related changes in trabecular and cortical bone microstructure. *International Journal of Endocrinology.* 2013; Article ID 213234, 9 pages.

78. Almeida M. Aging mechanisms in bone. *Bonekey Reports.* 2012;1(1).

79. Osteoporosis Canada. Osteoporosis Facts & Statistics. 2013; http://www.osteoporosis.ca/osteoporosis-and-you/osteoporosis-facts-and-statistics/.

80. Warriner AH, Saag KG. Osteoporosis diagnosis and medical treatment. *Orthopedic Clinics of North America.* 2013;44(2):125-135.

81. Papaioannou A, Morin S, Cheung AM, Atkinson S, Brown JP, Feldman S, Hanley DA, Hodsman A, Jamal SA, Kaiser SM, Kvern B, Siminoski K, Leslie WD. 2010 Clinical practice guidelines for the diagnosis and management of osteoporosis in Canada: A summary. *Canadian Medical Association Journal.* 2010;182(17):1864-1873.

82. Tajeu GS, Delzell E, Smith W, Arora T, Curtis JR, Saag KG, Morrisey MA, Yun H, Kilgore ML. Death, debility, and destitution following hip fracture. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2014;69(3): 346-353.

83. Ioannidis G, Papaioannou A, Hopman WM, Akhtar-Danesh N, Anastassiades T, Pickard L, Kennedy CC, Prior JC, Olszynski WP, Davison KS, Goltsman D, Thabane L, Gafni A, Papadimitropoulos, Brown JP, Josse RG, Hanley DA, Adachi JD. Relation between fractures and mortality: Results from the Canadian Multicentre Osteoporosis Study. *Canadian Medical Association Journal.* 2009;181(5):265-271.

84. Morin S, Lix LM, Azimaee M, Metge C, Caetano P, Leslie WD. Mortality rates after incident non-traumatic fractures in older men and women. *Osteoporosis International.* 2011;22(9):2439-2448.

85. Tarride JE, Hopkins RB, Leslie WD, Morin S, Adachi JD, Papaioannou A, Bessette L, Brown JP, Goeree R. The burden of illness of osteoporosis in Canada. *Osteoporos International.* 2012;23(11):2591-2600.

86. Vitetta L, Anton B. Lifestyle and nutrition, caloric restriction, mitochondrial health and hormones: Scientific interventions for anti-aging. *Clinical Interventions in Aging.* 2007;2(4):537-543.

87. Hertoghe T. The “multiple hormone deficiency” theory of aging: Is human senescence caused mainly by multiple hormone deficiencies? *Annals of the New York Academy of Sciences.* 2005;1057(1):448-465.

88. Copinschi G, Caufriez A. Sleep and hormonal changes in aging. *Endocrinology and Metabolism Clinics of North America.* 2013;42(2):371-389.

89. Barzilai N, Huffman DM, Muzumdar RH, Bartke A. The critical role of metabolic pathways in aging. *Diabetes.* 2012;61(6):1315-1322.

90. Horstman AM, Dillon EL, Urban RJ, Sheffield-Moore M. The role of androgens and estrogens on healthy aging and longevity. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2012;67(11):1140-1152.

91. Barron AM, Pike CJ. Sex hormones, aging and Alzheimer's disease. *Frontiers in Bioscience (Elite Edition).* 2013;4:976-997.

92. Girodano R, Bonelli L, Marinazzo E, Ghigo E, Arvat E. Growth hormone treatment in human ageing: Benefits and risks. *Hormones.* 2008;7(2):133-139.

93. Barzilai N, Gabriely I. Genetic studies reveal the role of the endocrine and metabolic systems in aging. *Journal of Clinical Endocrinology and Metabolism.* 2010;95(10):4493-4500.

94. Sonntag WE, Csiszar A, deCabo R, Ferrucci L, Ungvari Z. Diverse roles of growth hormone and insulin-like growth factor-1 in mammalian aging: Progress and controversies. *Journal of Gerontology Series A: Biological Sciences and Medical Sciences.* 2012;67A(6):587-598.

95. Sherlock M, Toogood A. Aging and the growth hormone/insulin like growth factor-I axis. *Pituitary*. 2007;10(2):189-203.

96. Tchernof A, Despres JP. Pathophysiology of human visceral obesity: An update. *Physiological Reviews.* 2013;93:359-404.

97. Sakuma K, Yamaguchi A. Sarcopenic obesity and endocrinal adaptation with age. *International Journal of Endocrinology.* 2013; Article ID 204164:1-12.

98. Huffman DM, Barzilai N. Role of visceral adipose tissue in aging. *Biochimica et Biophysica Acta (BBA) - General Subjects.* 2009;1790(10):1117-1123.

99. Chang AM, Halter JB. Aging and insulin secretion. *American Journal of Physiology - Endocrinology And Metabolism.* 2003;284(1):E7-E12.

100. Viljoen A, Sinclair AJ. Diabetes and insulin resistance in older people. *Medical Clinics of North America.* 2011;95:615-629.

101. Krentz AJ, Viljoen A, Sinclair A. Insulin resistance: A risk marker for disease and disability in the older person. *Diabetic Medicine.* 2013;30(5):535-548.

102. Public Health Agency of Canada. *Diabetes in Canada*. Ottawa, ON: Public Health Agency of Canada; 2011.

103. Public Health Agency of Canada, Canadian Institute for Health Information. *Obesity in Canada: A joint report from the Public Health Agency of Canada and the Canadian Institute for Health Information*. Ottawa, ON;2011.

104. Canadian Diabetes Association. *The cost of diabetes in Canada: The economic tsunami.* Toronto, ON: Canadian Diabetes Association; 2009.

105. Caruso C, Lio D, Cavallone L, Franceschi C. Aging, longevity, inflammation, and cancer. *Annals of the New York Academy of Sciences.* 2004;1028(1):1-13.

106. Pereira B, Ferreira MG. Sowing the seeds of cancer: Telomeres and age-associated tumorigenesis. *Current Opinion in Oncology.* 2013;25(1):93-98.

107. Canadian Cancer Society's Advisory Committee on Cancer Statistics. *Canadian Cancer Statistics 2013*. Toronto, ON: Canadian Cancer Society; 2013.

108. Niccoli T, Partridge L. Ageing as a risk factor for disease. *Current Biology.* 2012;22(7): R742-752.

109. Naylor RM, Baker DJ, van Deursen JM. Senescent cells: A novel therapeutic target for aging and age-related diseases. *Clinical Pharmacology & Therapeutics.* 2013;93(1):105-116.

110. Balducci L, Ershler WB. Cancer and ageing: A nexus at several levels. *Nature Reviews Cancer.* 2005;5(8):655-662.

111. Hoffe S, Balducci L. Cancer and age: General considerations. *Clinics in Geriatric Medicine.* 2012;28(1):1-18.

112. Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. *Lancet.* 1953;265(6796):1111-1120.

113. Paffenbarger RS Jr, Brand RJ, Sholtz RI, Jung DL. Energy expenditure, cigarette smoking, and blood pressure level as related to death from specific diseases. *American Journal of Epidemiology*. 1978;108(1):12-18.

114. Fletcher GF, Blair SN, Blumenthal J, Caspersen C, Chaitman B, Epstein S. Sivarajan Froelicher ES, Froelicher VF, Pina IL, Pollock ML. Statement on exercise. Benefits and recommendations for physical activity programs for all Americans. A statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation.* 1992;86(1):340-344.

115. Heart & Stroke Foundation of Canada. *Position Statement on Physical Activity*. Ottawa, ON: Heart & Stroke Foundation of Canada; 1993.

116. Bouchard C, Shephard RJ, Stephens T, (eds.). *Physical activity, fitness and health: International proceedings and consensus statement.* Champaign IL: Human Kinetics; 1994.

117. Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide to healthy active living*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1998.

118. Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for older adults*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1999.

119. Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for children*. Cat. No. H39-646/2002-2E. Ottawa, ON: Health Canada; 2002.

120. Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for youth*. Cat. No. H39-611/2002-2E. Ottawa, ON: Health Canada; 2002.

121. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scandinavian Journal of Medicine & Science in Sports.* 2006;16(S1):3-63.

122. Rhodes RE, Mark RS, Temmel CP. Adult sedentary behavior: A systematic review. *American Journal of Preventive Medicine.* 2012;42(3):e3-e28.

123. Kokkinos P. Physical Activity, Health Benefits, and Mortality Risk. *ISRN Cardiology.* 2012;2012:14.

124. Swift DL, Lavie CJ, Johannsen NM, Arena R, Earnest CP, O'Keefe JH, Milani RV, Blair SN, Church TS. Physical activity, cardiorespiratory fitness, and exercise training in primary and secondary coronary prevention. *Circulation Journal.* 2013;77(2):281-292.

125. Vina J, Sanchis-Gomar F, Martinez-Bello V, Gomez-Cabrera MC. Exercise acts as a drug; the pharmacological benefits of exercise. *British Journal of Pharmacology.* 2012;167(1):1-12.

126. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports.* 1985;100(2):126-131.

127. Physical activity and cardiovascular health: NIH consensus development panel on physical activity and cardiovascular health. *JAMA.* 1996;276(3):241-246.

128. Tremblay MS, Shephard RJ, Brawley LR. Research that informs Canada's physical activity guides: an introduction. *Applied Physiology, Nutrition & Metabolism.* 2007;32:S1-S8.

129. Norton K, Norton L, Sadgrove D. Position statement on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport.* 2010;13(5):496-502.

130. Sedentary Behavior Research Network. Letter to the editor: Standardized use of the terms "sedentary" and "sedentary behaviours". *Applied Physiology, Nutrition & Metabolism.* 2012;37:540-542.

131. Singh MA. Exercise to prevent and treat functional disability. *Clinics in Geriatric Medicine.* 2002;18:431-462.

132. Chodzko-Zajko W, Schwingel A, Park CH. Successful aging: The role of physical activity. *American Journal of Lifestyle Medicine.* 2009;3:20-28.

133. Concannon LG, Grierson MJ, Harrast MA. Exercise in the older adult: From the sedentary elderly to the masters athlete. *PM&R Journal.* 2012;4(11):833-839.

134. Heckman GA, McKelvie RS. Cardiovascular aging and exercise in healthy older adults. *Clinical Journal of Sport Medicine.* 2008;18(6):479-485.

135. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of physical activities: A second update of codes and MET values. *Medicine & Science in Sports & Exercise.* 2011;43(8):1575-1581.

136. Kesaniemi YA, Danforth E Jr, Jensen MD, Kopelman PG, Lefebvre P, Reeder BA. Dose-response issues concerning physical activity and health: An evidence-based symposium. *Medicine & Science in Sports & Exercise.* 2001;33(6Suppl):S351-358.

137. Haskell WL, Lee IM, Pate RR, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: Updated recommendations for adults from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116:1081-1093.

138. Allen J, Morelli V. Aging and exercise. *Clinics in Geriatric Medicine.* 2011;27:661-671.

139. King AC, King DK. Physical activity for an aging population. *Public Health Reviews.* 2010;32(2):401-426.

140. DiPietro L. Physical activity in aging: Changes in patterns and their relationship to health and function. *the journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2001;56(suppl 2):13-22.

141. Depp C, Vahia IV, Jeste D. Successful aging: Focus on cognitive and emotional health. *Annual Review of Clinical Psychology.* 2010;6(1):527-550.

142. Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE, Kho ME, Hicks A, LeBlanc AG, Zehr L, Murumets K, Duggan M. New Canadian physical activity guidelines. *Applied Physiology, Nutrition & Metabolism.* 2011;36:36-46.

143. World Health Organization Ageing and Health Programme. The Heidleberg Guidelines for promoting physical activity among older persons. Geneva: World Health Organization; 1996.

144. Daniels KM, Arena R, Lavie CJ, Forman DE. Cardiac rehabilitation for women across the lifespan. *The American Journal of Medicine.* 2012;125(9):937.e931-937.e937.

145. Warburton DER, Nicol CW, Bredin SSD. Prescribing exercise as preventive therapy. *Canadian Medical Association Journal.* 2006;174(7):961-974.

146. Statistics Canada. Physical activity during leisure time, by age group and sex. CANSIM Table 105-0501. 2013; http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health77a-eng.htm. Accessed July 12, 2013.

147. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity levels of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports.* 2011;22(1):7-14.

148. Gennuso KP, Gangnon RE, Matthews CE, Thraen-Borowski KM, Colbert LH. Sedentary behavior, physical activity and markers of health in older adults. *Medicine & Science in Sports & Exercise.* 2013;45(8):1493-1500.

149. Vegda K, Nie J, Wang L, Tracy CS, Moineddin R, Upshur R. Trends in health services utilization, medication use, and health conditions among older adults: a 2-year retrospective chart review in a primary care practice. *BMC Health Services Research.* 2009;9(1):217.

150. Linden M, Horgas AL, Gilberg R, Steinhagen-Thiessen E. Predicting health care utilization in the very old: the role of physical health, mental health, attitudinal and social factors. *Journal of Aging and Health.* 1997;9(1):3-27.

151. Ricketts TC, Goldsmith LJ. Access in health services research: The battle of the frameworks. *Nursing Outlook.* 2005;53(6):274-280.

152. Babitsch B, Gohl D, von Lengerke T. Re-revisiting Andersen's behavioral model of health services use: A systematic review of studies from 1998-2011. *GMS Psychosocial Medicine.* 2012;9(Doc 11):1-15.

153. Andersen RM, Newman JF. Societal and individual determinants of medical care in the United States. *Milbank Memorial Fund Quarterly Journal.* 1973;51:95-124.

154. Andersen RM. Behavioral model of families' use of health services. *Research Series No. 25*. Chicago, IL: Health Administration Studies, University of Chicago; 1968.

155. Andersen RM. Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior.* 1995;36(1):1-10.

156. Phillips KA, Morrison KR, Andersen R, LA A. Understanding the context of healthcare utilization: Assessing environmental and provider-related variables in the Behavioral Model of Utilization. *Health Services Research.* 1998;33(3):571-596.

157. Strain LA. Use of health services in later life: The influence of health beliefs. *Journal of Gerontology*. 1991;46(3):143-150.

158. Afilalo J, Marinovich A, Afilalo M, Colacone A, Léger R, Unger B, Giguère C. Nonurgent emergency department patient characteristics and barriers to primary care. *Academic Emergency Medicine.* 2004;11(12):1302-1310.

159. Ryan B, Stewart M, Campbell MK, Koval J, Thind A. Understanding adolescent and young adult use of family physician services: a cross-sectional analysis of the Canadian Community Health Survey. *BMC Family Practice.* 2011;12(1):118.

160. Sibley L, Weiner J. An evaluation of access to health care services along the rural-urban continuum in Canada. *BMC Health Services Research.* 2011;11(1):20.

161. Blackwell DL, Martinez ME, Gentleman JF, Sanmartin C, Berthelot JM. Socioeconomic status and utilization of health care services in Canada and the United States: Findings from a binational health survey. *Medical Care* 2009;47(11):1136-1146.

162. Guilcher SJT, Craven BC, McColl MA, Lemieux-Charles L, Casciaro T, Jaglal SB. Application of the Andersen's health care utilization framework to secondary complications of spinal cord injury: a scoping review. *Disability and Rehabilitation.* 2012;34(7):531-541.

163. Lai DWL. Intention of use of long-term care facilities and home support services by Chinese-Canadian family caregivers. *Social Work in Health Care.* 2008;47(3):259-276.

164. Herman KM, Ardern CI, Mason C, Brien SE, Katzmarzyk PT. Trends in physical activity research in Canada. *Applied Physiology, Nutrition, and Metabolism.* 2007;32(3):400-408.

165. Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

166. Shephard RJ. Employee health and fitness: The state of the art. *Preventive Medicine.* 1983;12(5):644-653.

167. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

168. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: An update. *Canadian Journal of Applied Physiology.* 2004;29(1):90-115.

169. Janssen I. Health care costs of physical inactivity in Canadian adults. *Applied Physiology, Nutrition, and Metabolism.* 2012;37(4):803-806.

170. Anderson LH, Martinson BC, Crain AL, Pronk NP, Whitebird RR, O'Connor PJ, Fine LJ. Health care charges associated with physical inactivity, overweight, and obesity. *Preventing Chronic Disease.* 2005;2(4):A09.

171. Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

172. Sari N. A short walk a day shortens the hospital stay: Physical activity and the demand for hospital services for older adults. *Canadian Journal of Public Health.* 2010;101(5):385-389.

173. Leigh JP, Fries JF. Health habits, health care use and costs in a sample of retirees. *Inquiry.* 1992;29(1):44-54.

174. Perkins AJ, Clark DO. Assessing the association of walking with health services use and costs among socioeconomically disadvantaged older adults. *Preventive Medicine.* 2001;32(6):492.

175. Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obesity Research.* 2005;13(8):1450-1457.

176. Borzecki AM, Lee A, Kalman D, Kazis LE. Do poor health behaviors affect health-related quality of life and healthcare utilization among veterans? *Journal of Ambulatory Care Management.* 2005;28(2):141-156.

177. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4): 392-410.

178. Andreyeva T, Sturm R. Physical activity and changes in health care costs in late middle age. *Journal of Physical Activity and Health.* 2006;3:S6-S19.

179. Nguyen HQ, Ackermann RT, Maciejewski M, Berke EM, Patrick M, Williams B, LoGerfo JP. Managed-Medicare health club benefit and reduced health care costs among older adults. *Preventing Chronic Disease.* 2008;5(1):1-10.

180. Petrella RJ, Pedersen L, Cunningham DA, Koval JJ, Paterson DH. Physician contact with older community patients: Is there an association with physical fitness? *Preventive Medicine.* 1999;29(6):571.

181. Dunlop S, Coyte PC, McIsaac W. Socio-economic status and the utilization of physicians' services: Results from the Canadian National Population Health Survey. *Social Science & Medicine.* 2000;51(2000):123-133.

182. Woolcott JC, Ashe MC, Millar WC, Shi P, Marra CA, PACC Research Team. Does physical activity reduce seniors' need for healthcare? A study of 24 281 Canadians. *British Journal of Sports Medicine.* 2010;44:902-904.

183. Ackermann RT, Cheadle A, Sandhu N, Madsen L, Wagner EH, LoGerfo JP. Community exercise program use and changes in healthcare costs for older adults. *American Journal of Preventive Medicine.* 2003;25(3):232-237.

184. Ackermann RT, Williams B, Nguyen HQ, Berke EM, Maciejewski ML, LoGerfo JP. Healthcare cost differences with participation in a community-based group physical activity benefit for Medicare managed care health plan members. *Journal of the American Geriatrics Society.* 2008;56:1459-1465.

185. Brown WJ, Hockey R, Dobson AJ. Physical activity, body mass index and health care costs in mid-age Australian women. *Australian and New Zealand Journal of Public Health.* 2008;32(2):150-155.

186. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, Wagner EH. The effect of strength and endurance training on gait, balance, fall risk and health services use in community-living older adults. *Journal of Gerontology.* 1997;52A(4):M218-M224.

187. Chen IJ, Chou CL, Yu S, Cheng SP. Health services utilization and cost utility analysis of a walking program for residential community elderly. *Nursing Economics.* 2008;26(4):263-269.

188. Courtney M, Edwards H, Chang A, Parker A, Finlayson K, Hamilton K. Fewer emergency readmissions and better quality of life for older adults at risk of hospital readmission: A randomized controlled trial to determine the effectiveness of a 24-week exercise and telephone follow-up program. *Journal of the American Geriatrics Society.* 2009;57(3):395-402.

189. Davis JC, Marra CA, Robertson MC, Khan KM, Najafzadeh MA, Ashe MC, Liu-Ambrose T. Economic evaluation of dose–response resistance training in older women: a cost-effectiveness and cost-utility analysis. *Osteoporos International.* 2011;22(5):1355-1366.

190. Davis JC, Marra CA, Robertson MC, Najafzadeh MA, Liu-Ambrose T. Sustained economic benefit of resistance training in community-dwelling senior women. *Journal of the American Geriatrics Society.* 2011;59:1232-1237.

191. Davis JC, Bryan S, Marra CA, Sharma D, Chan A, Beattie BL, Graf P, Liu-Ambrose T. An economic evaluation of resistance training and aerobic training versus balance and toning exercises in older adults with mild cognitive impairment. *PLoS ONE.* 2013;8(5):e63031.

192. Denkinger MD, Lukas A, Herbolsheimer F, Peter R, Nikolaus T. Physical activity and other health-related factors predict health care utilisation in older adults. *Zeitschrift für Gerontologie und Geriatrie.* 2012;45(4):290-297.

193. Holland SK, Greenberg J, Tidwell L, Malone J, Mullan J, Newcomer R. Community-based health coaching, exercise and health service utilization. *Journal of Aging and Health.* 2005;17(6):697-716.

194. Jacobs JM, Rottenberg Y, Cohen A, Stessman J. Physical activity and health service utilization among older people. *Journal of the American Medical Directors Association.* 2013;14(2):125-129.

195. Kemmler W, von Stengel S, Engelke K, Häberle L, Kalender WA. Exercise effects on bone mineral density, falls, coronary risk factors, and health care costs in older women: The randomized controlled senior fitness and prevention (SEFIP) study. *Archives of Internal Medicine.* 2010;170(2):179-185.

196. Kuriyama S, Hozawa A, Ohmori K, Suzuki Y, Nishino Y, Fujita K, Tsubono Y, Tsuji I. Joint impact of health risks on health care charges: 7-year follow-up of National Health Insurance beneficiaries in Japan (the Ohsaki Study). *Preventive Medicine.* 2004;39:1194-1199.

197. Liu-Ambrose TY, Ashe MC, Marra C, Physical Activity and Chronic Conditions Research Team. Independent and inverse association of healthcare utilisation with physical activity in older adults with multiple chronic conditions. *British Journal of Sports Medicine.* 2010;44(14):1024-1028.

198. Martinson BC, Crain AL, Pronk NP, O'Connor PJ, Maciosek MV. Changes in physical activity and short-term changes in health care charges: a prospective cohort of older adults. *Preventive Medicine.* 2003;37(319-326).

199. Munro JF, Nicholl JP, Brazier JE, Davey R, Cochrane T. Cost effectiveness of a community based exercise programme in over 65 year olds: cluster randomized trial. *Journal of Epidemiology and Community Health.* 2004;58 (1004-1010).

200. Nguyen HQ, Ackermann RT, Berke EM, Cheadle A, Williams G, Lin E, Maciejewski ML, LoGerfo JP. Impact of a managed-Medicare physical activity benefit on health care utilization and costs in older adults with diabetes. *Diabetes Care.* 2007;30(1):43-48.

201. Plotnikoff RC, Karunamuni ND, Johnson JA, Kotovych M, Svenson LW. Health-related behaviours in adults with diabetes: Associations with health care utilization and costs. *Canadian Journal of Public Health.* 2008;99(3):227-231.

202. Pronk NP, Goodman MJ, O'Connaor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *Journal of the American Medical Association.* 1999;282(23):2235-2239.

203. Smith TP, Kennedy SL, Smith M, Orent S, Fleshner M. Physiological improvements and health benefits during an exercise-based comprehensive rehabilitation program in medically complex patients. *Exercise Immunology Review.* 2006;12:86-96.

204. Hilbe JM. *Negative Binomial Regression.* Cambridge: Cambridge University Press; 2007.

CHAPTER THREE

METHODOLOGICAL OVERVIEW

With advances in analytical methods and software capabilities, new statistical approaches for analyzing health services utilization data have emerged in recent years.[1-3] In addition, there has been a shift towards the use of administrative health databases to examine questions around health services utilization.[1,4-6] In this chapter, the statistical properties of health services utilization data along with the general analytical approach taken in this thesis are outlined in Sections 3.1 and 3.2. In Section 3.3, a detailed description of the Saskatchewan Health (SK Health) administrative health databases used in Study 2 is provided and the procedures undertaken to gain access to the databases are outlined.[7] In addition, the strengths and limitations of administrative health data are outlined and the validity of the Saskatchewan administrative health databases in health research is discussed.

3.1 STATISTICAL PROPERTIES OF HEALTH SERVICES UTILIZATION DATA

Health services utilization data have several characteristics that make their analysis particularly challenging. In the literature, health services utilization is frequently measured as a count of services provided – for example, the number of physician visits, hospitalizations, nights spent in hospital, in a given time period. Although these types of outcomes are common in the literature, their analysis presents unique challenges.[8,9] Count data can be described as a non-negative integer without a known upper limit, which aim to track the number of specified events that occur in a given time interval.[8-10] This type of data often violate the assumption of normality associated with conventional linear regression modeling approaches, which can lead to inaccurate standard errors and an increase in Type I or Type II error.[2,10] In the case of health services utilization data, violations of the assumption of normality come about because of many individuals having zero or very few utilization events while a very few individuals have many utilization events, leading to data that is highly positively skewed to the right.[2] This type of data is better analyzed using a generalized linear model specifying a Poisson distribution rather than simple linear regression.[8] The Poisson distribution is used to model discrete counts and because it is somewhat similar to linear regression, the interpretation of these models is relatively straightforward.[9,10] It is important to note, however, that the Poisson distribution assumes that event occurrences are independent of each other and that the sample variance and sample mean are equal (equi-dispersion), both of which are frequently violated in health services utilization data. Health services utilization data is typically over-dispersed (the sample variance exceeds the sample mean). Failure to control for these violations will lead to inconsistent estimates, bias in standard error and inflated test statistics.[2,8] Negative binomial (NB) regression is an extension of Poisson regression in which lack of independence of observations and over-dispersion are accounted for by allowing the sample variance to be greater than the mean and through the introduction of a dispersion parameter which accommodates the unobserved heterogeneity in count data.[2,10,11]

3.2 APPROACHES TO STATISTICAL MODEL BUILDING

In this thesis negative binomial and logistic regression models were used to analyze health services utilization variables consisting of count data and dichotomous data, respectively. In Study 1, all clinically and theoretically important variables were included in all statistical models, regardless of their statistical significance in order to provide as complete control of confounding as possible.[12] This approach is often favored in epidemiological studies; however, it can be problematic in situations where the number of variables in the model is large relative to the number of respondents. A commonly used "rule of thumb" is that there should be a minimum of 5 to 10 observations per predictor.[13] Given that Study 2 has a relatively small sample size compared to the number of potential predictors, this approach would not be appropriate in this instance. Therefore, in Study 2 purposeful selection methods, as described by Hosmer & Lemeshow (2000), were employed in order to select covariates for the multivariate analyses.[12] The first step in this approach involves fitting univariate models to examine associations between the dependent variable and all independent variables of interest. Variables associated with the dependent variable at $p<0.25$ and those with known clinical and/or theoretical importance were retained for inclusion in the initial multivariate model. The second step involved fitting an initial multivariate model that included all the covariates identified at the first step. Variables that did not contribute significantly ($p<.05$) to the initial multivariate model were removed and a reduced model was fit. Potential confounding of the excluded variables was assessed by comparing the values of the estimated coefficients in the reduced model to their respective values in the initial model and if the difference between these values exceeded 20%, that variable was added back into the model. This verification process was completed one covariate at a time to ensure that all of the clinically and statistically important variables remained in the model. Once this process was complete, the linear assumptions of the continuous variables were checked and the model was assessed for interactions among the variables. The final step was to assess the goodness of fit of the model.[12]

There are several approaches to variable selection that are commonly used, but the overriding goal in statistical model building is to select those variables that result in the "best" model, that is, the most parsimonious model that is still an accurate reflection of the data.

Compared to stepwise selection procedures, purposeful selection has been shown to be superior in retaining significant covariates and confounding variables.[14]

3.3 SASKATCHEWAN HEALTH ADMINISTRATIVE HEALTH DATABASES

Under Saskatchewan's publicly funded health system, eligible residents have universal coverage for a wide range of health services, including physician and hospital services.[7] For members of certain groups, including the Canadian Forces and Royal Canadian Mounted Police and inmates of federal penitentiaries, health care is federally funded and therefore, members of these groups are not eligible for provincial health coverage.[7] In total, approximately 99% of Saskatchewan residents are eligible for provincial health coverage. Individuals are assigned a unique Health Services Number (HSN) which is then captured in records of health services utilization, allowing for the ongoing collection of health care information. Health care information collected by the Saskatchewan Ministry of Health is housed on several separate, but linkable, administrative databases.[7]

3.3.1 Accessing the Saskatchewan Health Databases

Saskatchewan Health's administrative health databases are a potentially rich source of data for health researchers; however, accessing this data is a complex, time-consuming and potentially costly process. The process and timeline undertaken in order to obtain administrative health services utilization data from the Saskatchewan Ministry of Health is outlined in Figure 3.1. A detailed proposal outlining the study objectives, methods, and data requirements was submitted on July 31, 2003 for approval by the Ministry's Data Access Review Committee so as to ensure compliance with data access and confidentiality policies (Appendix A-1).

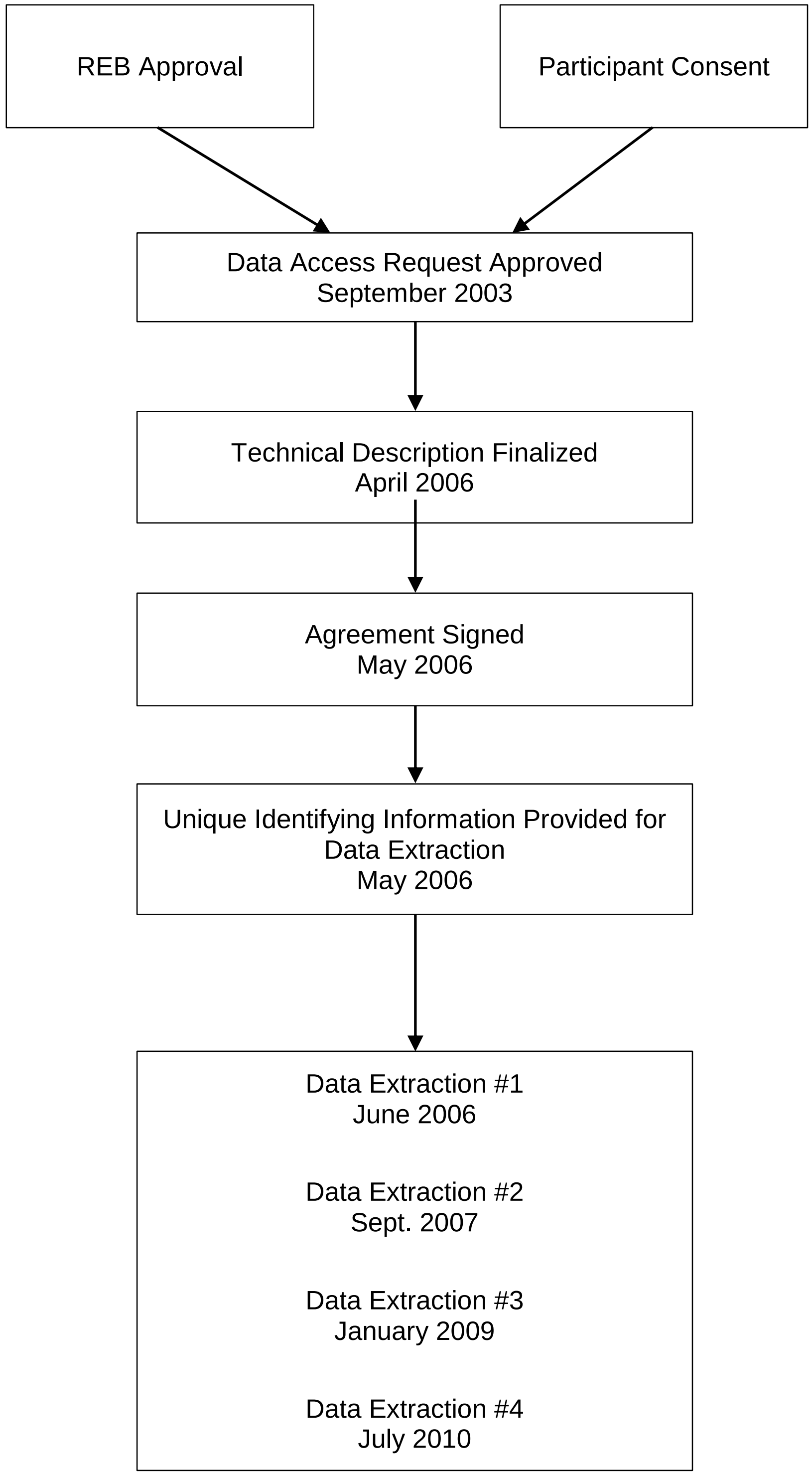


Figure 3.1 Process and timeline for accessing administrative health data from the Saskatchewan Ministry of Health

A total of five years of data was requested for each participant, covering their health services utilization for the year prior to enrolment in the 50+ *in motion* intervention, continuing through the intervention year and for three years following the intervention period. Approval for this project was received from the DARC committee on September 10, 2003.

Once approved, a detailed Technical Description of the data requirements was developed in consultation with a physician-researcher in internal medicine from the University of Saskatchewan and the data steward from the Ministry (Appendix A-2). The health services utilization and health care cost data requested was limited to services, diagnoses, and procedures with the potential to be influenced or affected by physical activity. The physician-researcher determined all relevant codes of interest to be included by reviewing the documentation specifying the codes for fees paid to physicians (fee schedule code; FSCs), diagnostic codes (ICD-9 or ICD-10-CA codes; International Statistical Classification of Diseases and Related Health Problems), and hospital procedure codes (CCP or CCI; Canadian Classification of Diagnostic, Therapeutic and Surgical Procedures and Canadian Classification of Health Interventions, respectively) and identified all relevant codes of interest to be included in the Technical Description. The technical description (Schedule C) was finalized and approved in April 2006, after which an Agreement was signed with the Saskatchewan Ministry of Health (Appendix A-2).

The dates of birth, HSNs, and researcher assigned identifiers of consenting participants were provided to the Ministry for the purposes of data abstraction. Participants' data across the pertinent databases were linked using the HSN and date of birth. The data were integrated and refined by the Ministry data steward, with the HSN replaced by the researcher assigned identifier in the data prior to their release. The first extraction of data was carried out in June 2006. Due to time lags between when health services utilization data is received by the Ministry of Health and when it is available for use by researchers, the final data extraction was not released until July 2010.

3.3.2 Description of the Saskatchewan Health Administrative Databases

The databases used in this thesis project, together with information regarding the available data elements and those that were requested, are detailed in Table 3.1 and are summarized below.

Population Registry: The population registry includes information for all residents eligible for Saskatchewan Health benefits. The following data were provided by Saskatchewan Health for all consenting participants: demographic information including date of birth, sex, an indicator of registered Indian status, dates of coverage initiation and termination, reason for coverage termination (death, emigration or study termination date) and an indicator for death.

Medical Services File: Medical services data is based primarily on physicians' claims for payment under a fee-for-service payment plan.[7] While the majority of physicians in Saskatchewan are remunerated in this way, some physicians fall under an alternative payment plan (i.e. salary, contract) and unless they chose to shadow bill Saskatchewan Health for their services, this information would not have been captured in this database.[7] Medical services from non-physicians (i.e. nurse practitioners) were not abstracted for this study.

Prior to release, medical services data were collapsed from service-based records such that all services delivered to a single person by a single practitioner for the same diagnosis on the same day at the same clinic and same location of service were reduced to a single visit record.[7] The released datafile contained information related to medical practitioner specialty (family practice, specialist or other) as well as service and diagnostic information including the date of service, diagnosis, and the approved amount paid for the service.

Hospital Services File: Information about all acute care in-patient hospital separations and day surgeries was provided in the hospital services datafile. This data included the following variables: admission date, discharge date, type of admission (day surgery; inpatient), diagnosis(es), diagnosis type (most responsible; pre-admission co-morbidity; post-admission co-morbidity; secondary; external cause of injury), procedure(s) performed, date of procedure, and intensity weight.[7] The intensity weight reflects hospital case resource consumption based on the assigned case mix group – a system used to classify patient episodes based on patient-level clinical data (most responsible diagnosis, intervention, comorbidity, and age).[15] For inpatient hospital stays, the intensity weight is referred to as the resource intensity weight (RIW), while for day surgery hospital admissions it is referred to as the day procedure group weight (DPG). Both RIWs and DPGs are determined by the Canadian Institute for Health Information and can be used to calculate the cost of a given hospital stay by multiplying the assigned weight by the provincial estimate of funding per weighted case (estimated based on hospitalizations funded through the acute care funding pool) for a given fiscal year.[7,15] It should be noted that certain services, including cardiac catheterization, dialysis, radiation therapy, rehabilitation, and mental health services are not funded through the acute care funding pool.[7,15]

Table 3.1 Overview of Saskatchewan Ministry of Health administrative databases[7]

Database Description		Select data elements in database	Data elements requested from Saskatchewan Health
Population Registry	Includes all residents eligible for Saskatchewan Health benefits. As of June 30, 2009, the eligible population was 1,036, 284	▪ name ▪ Health Services Number (HSN) ▪ sex ▪ date of birth ▪ residence information ▪ dates of coverage initiation & termination ▪ reason for coverage termination ▪ indicator for registered Indian status ▪ indicator for current social assistance recipients receiving extended health benefits.	▪ sex ▪ date of birth ▪ dates of coverage initiation & termination ▪ reason for coverage termination ▪ indicator for registered Indian status
Medical Services File	All members of the covered population are eligible to receive benefits for insured medical services including anesthesia, diagnostic, obstetric and surgical services. Certain medical services are not covered, including: cosmetic surgery, examinations for employment or insurance purposes.	Patient information ▪ HSN ▪ age, sex ▪ location of residence Physician Information ▪ physician specialty ▪ referring physician, if applicable ▪ physician identification number (linkable to physician registry for additional information regarding physician) Service/Diagnostic Information ▪ date, location of service (e.g. office, inpatient, outpatient) ▪ service code, type of service ▪ diagnosis ▪ payment information (amount paid, date)	Physician Information ▪ physician specialty (family practice, specialist, other) Service/Diagnostic Information ▪ date of service ▪ diagnosis ▪ approved amount paid Specific physician fee for service (FSC) codes and diagnostic (actual ICD-9) codes were reported for specified procedures/diagnoses only. All other diagnoses were deleted and/or grouped.

Table 3.1 continued

Database Description		Select data elements in database	Data elements requested from Saskatchewan Health
Hospital Services File	All members of the covered population are eligible to receive benefits for medically necessary hospital services without charge Included: ▪ All acute care in-patient separations, day surgeries, and in-patient psychiatric separations. ▪ Out-of-province hospital separations for Saskatchewan beneficiaries	Each hospital separation record includes: Patient information ▪ HSN ▪ sex, date of birth ▪ residence ▪ indicator for registered Indian status Diagnostic &Treatment Information ▪ most responsible diagnosis ▪ other diagnoses ▪ procedure(s) ▪ accident code (external cause code) Other ▪ admission and discharge dates ▪ length of stay ▪ admission and separation types ▪ case mix group ▪ resource intensity weight ▪ attending physician ▪ attending surgeon (if applicable) ▪ hospital identification number	▪ admission and discharge dates ▪ admission type (day surgery; inpatient) ▪ diagnosis(es) ▪ diagnosis type (most responsible; pre-admission co-morbidity; post-admission co-morbidity; secondary; accident code) ▪ procedure(s) performed ▪ date of procedure ▪ resource intensity weight Specific hospital diagnostic and procedure codes and physician FSC codes were reported for specified diagnoses only. All other diagnoses/procedures were deleted and/or grouped.

3.3.2 Strengths and Limitations of Administrative Health Data

The use of administrative health data offers several advantages compared to other types of health services data (e.g. self-reported health data) including accurate and complete records of healthcare use without recall bias, inclusion of entire populations, and follow-up over multiple years.[6,16,17] However, the use of administrative health data is not without its limitations.[4,6,16,18] Typically, gaining access to administrative health data for research services is a complex, time-consuming and costly undertaking and the lack of a standard, systematic approach across provinces and territories makes it all the more challenging to undertake studies using linked administrative health data at a national level.[19] Another issue is that administrative health data is not collected with research in mind, consequently these databases often lack clinically important information because it did not serve the original purposes for which the data were collected.[3,4,6,20,21] Furthermore, inconsistencies between service providers in data coding and incomplete or incorrect recording of diagnostic and procedural data may undermine the accuracy of this type of data.[4,6,16,18,22] Lastly, researchers face strict regulations and limits with regards to access and use of administrative health data due to concerns with privacy and confidentiality.[4,6,19,21,23]

While these limitations should be kept in mind, a number of approaches are available to minimize the potential for error including linkage of administrative health care data with other centralized databases, examining co-morbid diagnoses and prior use of health services to partially account for severity of illness, and the use of statistical approaches to address issues of non-random attrition and missing data.[3,16,18]

3.3.3 Validity & Reliability of Saskatchewan Health Administrative Databases

In studies involving the use of administrative databases, the validity of the data elements within the database are of paramount importance.[17] Of primary concern is measurement validity – the degree of concordance between the administrative data and the information from which it was generated and external validity – the extent to which the information available from a database is generalizable to other jurisdictions.[22,24] Evaluating the measurement validity of a database is a complex process, ideally involving a combination of several methods including the re-abstraction of patient charts, the use of other information about patients' health status, such as general population-based health surveys, assessments of the consistency of information between the separate databases, evaluations of surrogate markers of disease and analyses of logically time-sequenced relationship between medical events within the data.[24] These assessments should be supported by a careful assessment of the external validity of the data given that social, political, cultural and historical contextual factors along with limitations in the population structure covered by the database may all limit the generalizability of the data.[24]

The Saskatchewan administrative health databases have been used extensively for research purposes.[25] Data validity, particularly as it relates to diagnostic coding, is a critical prerequisite for their use in health research.[25] At the Ministry level, various claims processing systems have built-in audit and eligibility checks; however, published studies assessing the validity of these databases are relatively scarce.[19,24-31] Studies published between 1985 and 2000 have examined the validity of the Saskatchewan administrative databases in relation to rheumatoid arthritis,[30] ischemic heart disease and chronic obstructive pulmonary disease (COPD),[28] cholecystectomy,[32] hysterectomy,[26,32] psychiatric disorders,[29] depression,[29,31] and stroke.[27] A summary of these findings follows below.

Tennis et al, (1993) published an abstraction study of rheumatoid arthritis diagnoses and reported that there was excellent agreement (97%) between the hospital separations database and abstracted hospital records in non-diagnostic information but that the level of agreement between the data sources in diagnostic information, while reasonably good, varied by diagnosis and not all chart diagnoses were included in the administrative database.[30] When the application of American Rheumatological Association diagnostic criteria for rheumatoid was applied, it was found that 85% of rheumatologist-hospitalized patients were correctly classified as having rheumatoid arthritis while for patients who were admitted by physicians other than rheumatologists, 60% did not meet ARA criteria, most often because of a lack of recorded information in the hospital charts.[30] After publishing a series of individual validation studies for various diagnoses, Rawson & D'Arcy (1998) published a broad assessment of the validity of the Saskatchewan Ministry of Health administrative healthcare utilization databases, incorporating data from their earlier work and concluded that there is a high level of agreement (ranging between 84% and 97%) between hospital discharge data and medical chart records for personal and demographic characteristics, two surgical procedures (cholecystectomy and hysterectomy), and five out of six discharge diagnoses (acute myocardial infarction, ischemic heart disease, emphysema, chronic airways obstruction, asthma). The general conclusions put forth by Rawson & D'Arcy's (1998) regarding the validity of the Saskatchewan administrative health databases are presented in Table 3.2.[24] In this paper, Rawson and D'Arcy also highlighted the need for further validation of the Saskatchewan databases across a wider range of health conditions and procedures.[24]

Table 3.2. General conclusions about the validity of patient characteristics, surgical procedures, and diagnoses in the Saskatchewan datafiles (Source: Rawson & D'Arcy, 1998[24])

	External Consistency[a]	Internal Consistency[b]	Contextual Consistency[c]
Personal characteristics	Excellent	Not applicable	Not applicable
Surgical procedures	Excellent	Excellent	Very cohesive
More precisely defined medical diagnoses	Excellent	Good to very good	Very cohesive
Less precisely defined medical diagnoses or those requiring laboratory test results	Very good	Poor	Cohesive
More precisely defined psychiatric diagnoses	Very good	Good	Cohesive
Less precisely defined psychiatric diagnoses	Poor	Poor to fair	Reasonably cohesive

Notes:

[a] The concordance between data in administrative datafiles and the information/records that generated them

[b] The concordance of data held on separate but linkable administrative datafiles

[c] The concordance between data in administrative datafiles and the contextual information surrounding the medical event (i.e. logically time-sequenced relationships)

In 1999, Lui et al examined the validity of stroke diagnosis on hospital discharge records, comparing the predictive value of diagnostic coding between tertiary-care and community hospitals.[27] While the predictive value of a primary diagnosis of stroke was approximately 90% in tertiary-care hospitals, it was considerably lower (78%) in community hospitals, leading the authors to conclude that high levels of regional variation in stroke diagnostic coding limits the use of hospital discharge data for stroke surveillance.[27]

West and colleagues (2000) assessed the validity of the Saskatchewan administrative health databases for studies of depression and its treatment.[31] This study compared the depression diagnoses from the Physician Services File to those abstracted from patient medical records in a stratified random sample of 600 individuals from a cohort of new antidepressant users identified in the Prescription Drug File. The level of agreement between the Physician Services File and abstracted patient charts was similar to that reported by Rawson and colleagues (1997) for a depression diagnosis (77% vs 73%).[29,31] With a good level of agreement in the diagnostic information and classification of patients between the two sources of data, the authors concluded that the Saskatchewan administrative health databases are a valid source of data for depression research.[31]

Although there are a limited number of validation studies specific to the Saskatchewan context, the broader literature provides general support for the validity of administrative health data.[25,33] In Canada, administrative databases are increasingly being used to conduct pan-Canadian studies on population health and the use of health services.[17,19] For example, certain administrative health data collected by the provinces/territories is reported to the Canadian Institute for Health Information (CIHI) where it is then aggregated to provide high quality data on standard indicators of health system performance which are published on an annual basis. Furthermore, aggregated data is available to federally and provincial/territorial health policymakers and planners, as well as to researchers and the general public.[17,34] Administrative health data are a rich resource and offer extensive opportunities for health-related research; however the unique nature of this data presents specific challenges that, if not considered, may compromise study validity.[4,6] It is important to recognize the potential issues and take steps, when possible, to minimize the risks they present in order to ensure that proper conclusions can be drawn. As administrative health data systems improve and the universality and level of detail available within these databases grow, the validity and versatility of these databases in health research will only be further enhanced.[4]

3.4 LITERATURE CITED

1. Diehr P, Yanez D, Ash A, Hornbrook M, Lin DY. Methods for analyzing health care utilization and costs. *Annual Review of Public Health.* 1999;20:125-144.

2. Yaacob WFW, Lazim MA, Wah YB. A practical approach in modeling count data. *Proceedings of the Regional Conference on Statistical Sciences 2010*. Malaysia: Malaysia Institute of Statistics; 2010.

3. Birnbaum HG, Cremieux PY, Greenberg PE, LeLorier J, Ostrander JA, Venditti L. Using healthcare claims data for outcomes research and pharmacoeconomic analyses. *Pharmacoeconomics.* 1999;16(1):1-8.

4. Schneeweiss S, Avorn J. A review of uses of health care utilization databases for epidemiologic research on therapeutics. *Journal of Clinical Epidemiology.* 2005;58(4):323-337.

5. Virnig BA, McBean M. Administrative data for public health surveillance and planning. *Annual Review of Public Health.* 2001;22:213-230.

6. Riley GF. Administrative and claims records as sources of health care cost data. *Medical Care.* 2009;477(7 Suppl 1):S51-S55.

7. Saskatchewan Ministry of Health. *Health Services Databases: Information document.* Epidemiology & Research Unit Population Health Branch, ed. Regina, SK: Saskatchewan Ministry of Health; 2010.

8. Hilbe JM. *Negative Binomial Regression.* Cambridge: Cambridge Unviersity Press; 2007.

9. Twisk JWR. *Applied Longitudinal Data Analysis for Epidemiology - A Practical Guide.* Cambridge: Cambridge University Press; 2003.

10. Karazsia BT, van Dulmen MHM. Regression models for count data: illustrations using longitudinal predictors of childhood injury. *Journal of Pediatric Psychology.* November 1, 2008 2008;33(10):1076-1084.

11. Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

12. Hosmer DW, Lemeshow S. *Applied Logistic Regression.* New York: John Wiley & Sons, Inc; 2000.

13. Tbachnick BG, Fidell LS. *Using Multivariate Statistics.* Boston, MA: Pearson Education Inc; 2007.

14. Bursac Z, Gauss CH, Williams DK, Hosmer D. Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine.* 2008;3(1):17.

15. Canadian Institute for Health Information. *CIHI Data and Standards: Day Procedure Groups (DPG).* 2010; http://www.cihi.ca/CIHI-ext-portal/internet/en/document/standards+and+data+submission/standards/case+mix/casemix_dpg.

16. Bernatsky S, Lix L, O'Donnell S, LaCaille D, Network C. Consensus statements for the use of administrative health data in rheumatic disease research and surveillance. *The Journal of Rheumatology*. January 1, 2013 2013;40(1):66-73.

17. Lix LM, Walker R, Nesdole R, Yang J, Chen G, for the CHEP-ORTF Hypertension Outcomes and Surveillance Team. Features of physician services databases in Canada. *Chronic Diseases and Injuries in Canada.* 2012;32(4):186-193.

18. Baron JA, Weiderpass E. An introduction to epidemiological research with medical databases. *Annals of Epidemiology.* 5// 2000;10(4):200-204.

19. Raina PS, Kirkland SA, Wolfson C, Szala-Meneok K, Griffith LE, Keshavarz H, Uniat J, Furlini L, Angus CL, Strople G, Pelletier A. Accessing health care utilization databases for health research: A Canadian longitudinal study on aging feasibility study. *Canadian Journal on Aging.* 2009;28(Special Issue 03):287-294.

20. van Walraven C, Austin P. Administrative database research has unique characteristics that can risk biased results. *Journal of Clinical Epidemiology.* 2012;65:126-131.

21. Downey W, Beck P, McNutt M. Health databases in Saskatchewan. In: Strom BL, ed. *Pharmacoepidemiology*. Third ed. Chichester, NY: Wiley; 2000.

22. van Walraven C, Bennett C, Forster AJ. Administrative database research infrequently used validated diagnostic or procedural codes. *Journal of Clinical Epidemiology.* 2011; 64(10):1054-1059.

23. Yip AM, Kephart G, Rockwood K. Linkage of the Canadian Study of Health and Aging to provincial administrative health care databases in Nova Scotia. *International Psychogeriatrics.* 2001;13(SupplementS1):147-158.

24. Rawson NSB, D'Arcy C. Assessing the validity of diagnostic information in administrative health care utilization data: experience in Saskatchewan. *Pharmacoepidemiology and Drug Safety.* 1998;7(6):389-398.

25. Tricco AC, Pham B, Rawson NSB. Manitoba and Saskatchewan administrative health care utilization databases are used differently to answer epidemiologic research questions. *Journal of Clinical Epidemiology.* 2008;61(2):192-197.e112.

26. Edouard L, Rawson NS. Reliability of the recording of hysterectomy in the Saskatchewan health care system. *British Journal of Obstetrics & Gynaecology.* 1996;103(9):891-897.

27. Lui L, Reeder B, Shuaib A, Mazagri R. Validity of stroke diagnosis on hospital discharge records in Saskatchewan, Canada: Implications for stroke surveillance. *Cerebrovascular Disease.* 1999;9(224-30).

28. Rawson NSB, Malcolm E. Validity of the recording of ischaemic heart disease and chronic obstructive pulmonary disease in the Saskatchewan health care datafiles. *Statistics in Medicine.* 1995;14(24):2627-2643.

29. Rawson NSB, Malcolm E, D'Arcy C. Reliability of the recording of schizophrenia and depressive disorder in the Saskatchewan health care datafiles. *Social Psychiatry and Psychiatric Epidemiology.* 1997;32(4):191-199.

30. Tennis P, Bombardier C, Malcolm E, Downey W. Validity of rheumatoid arthritis diagnoses listed in the Saskatchewan hospital separations database. *Journal of Clinical Epidemiology.* 1993;46(7):675-683.

31. West SL, Richter A, Melfi CA, McNutt M, Nennstiel ME, Mauskopf JA. Assessing the Saskatchewan database for outcomes research studies of depression and its treatment. *Journal of Clinical Epidemiology.* 2000;53(823-831).

32. Rawson NSB, Malcolm E. *Validity of the recording of cholecystectomy and hysterectomy in the Saskatchewan Health care datafiles.* Saskatoon, SK: Pharmacoepidemiology Research Unit;1995.

33. Peabody JW, Luck J, Jain S, Bertenthal D, Glassman P. Assessing the accuracy of administrative data in health information systems. *Medical Care.* 2004;42(11):1066-1072.

34. Canadian Institute for Health Information. *CIHI Annual Report, 2012-2013: Better data. Better decisions. Healthier Canadians.* Ottawa, ON;2013.

CHAPTER FOUR

STUDY ONE

PHYSICAL INACTIVITY AND HEALTH SERVICES UTILIZATION AMONG OLDER CANADIANS: FINDINGS FROM THE CANADIAN COMMUNITY HEALTH SURVEY

4.1 INTRODUCTION

The importance of physical activity (PA) in reducing chronic disease and maintaining good health and functional independence has been well documented.[1-5] The health benefits of exercise, including enhanced cardiovascular functioning, improved glucose tolerance and obesity reduction, are well known.[1-3,6] Improvements in conditions such as osteoporosis, sarcopenia and certain forms of cancer[1,2,4,5,7], positive changes in mental health, particularly related to depression and stress management, and improvements in cognitive ability, quality of life and well-being[4,5] have also been linked to increased PA levels.

Given the strong associations between PA and the aforementioned chronic conditions, the societal and economic implications of a physically inactive population are thought to be substantial.[8,9] Globally, it is estimated that 6–10% of premature deaths each year can be attributed to physical inactivity alone, including approximately 30% of cases of ischemic heart disease and approximately 15% of cases of T2DM and breast, colon and rectal cancers worldwide.[8,9] In Canada, it has been estimated the total health care costs of physical activity in 2009 were $6.8 billion and that just a 10% reduction in physical inactivity would result in a decrease in direct health care expenditures of approximately $150 million per year.[10-12] Although the importance of being physically active is widely acknowledged among the Canadian population, levels of physical activity remain low, particularly among older adults.[13,14] The most recent estimates suggest that the vast majority of middle-aged (40–59 yrs.) and older adults (60–

79 yrs.) are inactive, with fewer than 15% accumulating the recommended 150 minutes per week of moderate-vigorous PA.[14] Despite targeted strategies to increase physical activity in this segment of the population, fewer than 10% of older adults meet current physical activity recommendations.[14] Physical inactivity among older adults is of particular concern in many industrialized countries, including Canada, because of the important societal implications associated with population aging.[15] By 2036 it is expected that 1 in 4 Canadians will be 65 years of age or older.[16] Aging, like physical inactivity, is associated with an increase in the incidence and prevalence of most chronic conditions along with impairment and disability associated with functional decline. By age 65, 77% of men and 85% of women will have at least one chronic condition, the most prevalent being cardiovascular disease, cancer, respiratory disease, arthritis and diabetes.[17,18] Given that the average life expectancy at 65 years of age is now 21.5 years for women and 18.3 years for men, a significant proportion of the population will require ongoing, long term medical care to manage their conditions.[19] There is great concern that the increasing chronic care needs of older adults will place considerable strain on the health care system, both in terms of its capacity to meet an increasing demand for services and its ability to sustain the current level of service provision in the face of increasing costs.[20,21] For this reason there has been a growing interest among policymakers in the potential role of PA as a strategy to mitigate these challenges.[15,22,23]

Physical inactivity has been shown to be positively associated with health service utilization and costs; however, the literature in this area is quite limited.[24,25] Two widely cited studies of the economic burden of physical inactivity estimate that ~2.5% of direct health care costs in Canada can be attributed to physical inactivity.[10,11] An update of these papers, using newly available objectively measured physical inactivity prevalence estimates, indicates that physical inactivity now accounts for 3.6%-3.8% of overall health care costs.[12] It should be noted that these studies employed an indirect cost-of-illness approach, using population attributable fractions (PAF) estimated for each condition rather than individual-level data to model costs.[10,26] Because the cost-of-illness method is based on population-level relative risk estimates, it is not able to account for factors other than physical inactivity that may also contribute to costs.[12,26,27] Other studies have used person-level data to examine the association between PA and health service utilization, including physician and hospital services[26-34]; however few of these have specifically considered the older adult population[34-38] and/or the Canadian context.[34,36,39-43]

In studies of PA and health services utilization specifically in the Canadian older adult population, the findings have been somewhat mixed. Dunlop et al (2000) examined the relationship between socioeconomic status and use of general and specialist physician services and found that physical inactivity was among the factors associated with the number of visits to specialist physicians but not general physicians.[40] Furthermore, the association between PA and specialist visits differed by sex and the way in which the variable was operationalized. When examining use (≥ 1 visit) versus non-use (no visits) of specialist services, moderately active and inactive males were 6% and 20% more likely than active males, respectively, to have used specialist services in the previous year; however, among females, these associations were not significant. When high (≥ 6 visits) and low use (< 6 visits) of specialist services was examined, significant associations between physical inactivity and high use of specialist services were seen in females but not males, with moderately active females being 13% less likely and inactive females 32% more likely than active females to be high users of specialist visits.[40] More recently, Woolcott et al (2010) compared ‘general health visits’ (including general practitioner and specialist physicians as well as other allied health care providers) between active and inactive respondents in a nationally representative sample of 24,281 older adults aged 65 years and older.[42] In this study, physically active seniors reported significantly fewer 'general health visits' than their inactive counterparts (8.15 vs. 11.76 visits/yr).[42] In contrast, Plotnikoff et al found that LTPA was not significantly associated with either general practitioner (GP) or specialist visits in a sample of 2300 individuals with T1D or T2D.[43]

The results of studies of LTPA and hospital services utilization are also somewhat inconsistent. Sari (2010) recently examined the association between PA and the demand for hospital services in adults 65 years of age and older and found leisure time physical activity (LTPA) to be negatively associated with hospital stays, concluding that even small increases in LTPA could translate into a decrease in hospital stays of 16% to 19% in inactive older adults.[34] In a similar study, Woolcott et al (2010) reported that physically inactive older adults were 84% more likely to be hospitalized in the previous 12-months and spent, on average, more than three times the number of days in hospital compared to their active counterparts.[42] In contrast to these studies, Plotnikoff et al (2010) failed to find a significant association between LTPA and the number of hospital visits in their sample of adults with T1D and T2D, after adjusting for other factors associated with health services utilization.[43]

Studies of physical activity and healthcare costs also report equivocal findings. Liu-Ambrose et al (2010) examined the association of PA and direct healthcare costs in 209 community-dwelling older adults with multiple chronic conditions and found that PA was found to make a small but significant contribution, accounting for approximately 3.3% of the variance in direct healthcare costs, after adjustment for age, sex, number of chronic conditions, general balance and mobility and cognitive function.[41] In contrast, Plotnikoff et al (2010) found no significant associations between LTPA and total physician costs, after adjusting for demographic, health, and behavioral factors associated with health services utilization.[43] It should be noted, however, that when only behavioural factors were considered, Plotnikoff et al (2010) reported significant negative associations between LTPA and total physician costs among older adults with TID or T2D – a discrepancy which is not addressed in the discussion of their findings.[43]

Although these studies are encouraging, there remain considerable gaps in our understanding of the relationship between physical activity and health services utilization, particularly among older adults.[24,25,44] Along with the general lack of Canadian data, wide variations in study methodologies limit the extent to which we can draw conclusions from the literature.[25] There is a need for additional studies that include comprehensive sets of observed covariates and appropriate statistical methods in order to gain better insight into the relationship between physical activity and health services utilization. Therefore, the purpose of this study was to examine the relationship between LTPA and health services utilization in a nationally representative sample of community-dwelling adults aged 50 years and older. Based on previous research, it was hypothesized that LTPA would be associated with lower levels of health services utilization.

4.2 METHODS

In order to undertake this study, an application was made to the Research Data Centres Program of the Social Sciences and Humanities Research Council (SSHRC) in February, 2008 requesting access to the confidential micro-data files for Cycle 3.1 of the Canadian Community Health Survey (CCHS). Approval of the project was granted on April 1, 2008, following a successful background security check and evaluation of the proposed research by the RDC-

Access Granting Committee. A copy of the submitted research proposal and the letter of approval from SSHRC are provided in Appendix B-1 and B-2, respectively.

4.2.1 Canadian Community Health Survey

This study involved a secondary analysis of data from the Cycle 3.1 of the Canadian Community Health Survey (CCHS). The CCHS is a nationally representative survey conducted by Statistics Canada with the purpose of providing cross-sectional data related to health determinants, health status and health services utilization for the Canadian population aged 12 or older.[45,46] The CCHS covers approximately 98% of the Canadian population living in private and occupied dwellings in all provinces and territories although certain population groups, including individuals living on reserve, institutional residents, full-time members of the Canadian Forces and residents of certain remote regions are excluded.[46] Data collection for CCHS Cycle 3.1 took place from January – December 2005 using computer-assisted personal and telephone interviews. In order to minimize possible seasonal effects on estimates of certain key characteristics such as PA, the initial sample of households was allocated at random, within each health region, over the 11 months of data collection.[46]

4.2.2 Participants

In total 168,464 households were selected to participate in the CCHS Cycle 3.1. A response was obtained for 143,076 of the selected households, resulting in a household-level response rate of 84.9%. Of the 143, 076 individuals selected (one person per household) to participate, valid interviews were conducted with 132,947 individuals yielding an individual-level response rate of 92.9%. When weighted, this sample represents 27.1 million people.[46,47]

The present analysis was restricted to those respondents aged 50 years and older with non-missing PA and health services utilization data, resulting in an unweighted sample of 56,652 adults.

4.2.3 Measures

A brief summary of all study variables as they were included in the analyses is presented below. Table 2.1 provides detailed descriptions and coding/recoding information for all dependent and independent variables.

4.2.3.1 Dependent Variables

Health services utilization was characterized as the use of general physician (GP) services, specialist physician services and hospital services in the 12-month period prior to the survey. In modeling each type of health services utilization, both service contacts (services used vs. services not used) and volume of service use were of interest because of the probable differences in the determinants of each type of utilization.[48] For example, the decision to see a physician one time is primarily that of the individual patient while physicians themselves may influence the volume and/or frequency of future visits.[48] Each dependent variable is described in further detail below.

General physician services

Respondents were asked to report the number of consultations, including telephone consultations, with a family doctor or GP physician in the 12 month period preceding the survey.[49] In addition to this continuous variable indicating volume of service use, two dichotomous variables were constructed – one to indicate contact with a GP physician (use versus non-use) and one to indicate high use of services. Given that there is little consensus in the literature on what constitutes high use of physician services, the cut-point for high use of physician services was defined *a priori* as the population mean plus one standard deviation (SD).[40,50]

Specialist physician services

Respondents reported the number of consultations, including telephone consultations, with medical doctors other than GP or family doctors (excluding eye specialists) in the year prior to the survey.[49] As was the case with GP services, three variables were used to describe specialist physician services: a dichotomous variable comparing those with at least one specialist visit to those with no specialist visits, a continuous variable indicating volume of specialist physician contacts, and a dichotomous variable examining high use of specialist physician services (population mean + 1 SD).

Hospital services

Respondents were asked to indicate if they had stayed overnight as a patient in a hospital in the 12 months preceding the survey and if so, to recall the number of nights spent in hospital.[49] Two variables were used to describe the use of hospital services: a dichotomous variable indicating if the respondent had been hospitalized in the previous year and for those reporting a hospitalization, a continuous variable indicating the total number of nights spent in hospital.

4.2.3.2 Independent Variable of Interest

The main independent variable of interest was self-reported leisure time physical activity (LTPA) over the 3 months prior to the survey interview. Using an adaptation of the Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ), respondents were asked about their participation in 21 specified physical activities, participation frequency and average activity duration.[49] Respondents could also report information for up to 3 additional activities. Average daily energy expenditure during LTPA was calculated based on the reported frequency and duration per session and a fixed assigned metabolic equivalent (MET) value associated with each reported type of activity with the result expressed in kilocalories expended per kilogram of body weight per day (KKD).[49] A Physical Activity Index (PAI) was used to categorize respondents as active (>3.0 KKD), moderately active (1.5 to 3.0 KKD) and inactive (<1.5 KKD), whereby 3.0 KKD reflects, on average, the equivalent of 60 minutes of moderate intensity PA daily, as recommended by public health guidelines in Canada.[51]

Table 4.1 Description of dependent and independent variables included in the study

Variable	CCHS Description[49]	Variables*
Dependent Variables		
Use of GP Services	The number of consultations, including over the phone, with a family doctor or general practitioner in the last 12 months?	• Volume of services used # of contacts • Use vs. Non-use *No visits* / ≥ 1 visits • High Use *< 9 visits* / ≥ 9 visits
Use of Specialist Services	The number of consultations, including over the phone, with any other medical doctor (excluding ophthalmologist) in the last 12 months?	• Volume of services used # of contacts • Use vs. Non-use *No visits* / ≥ 1 visits • High Use *< 3 visits* / ≥ 3 visits
Use of Hospital Services	In the past 12 months, have you been a patient overnight in a hospital, nursing home or convalescent home?	• Use vs. Non-use *No hospitalizations* / ≥ 1 visits
	If hospitalized overnight - How many nights in the past 12 months?	• Volume of services used # of nights
Independent Variable of Interest		
Physical Activity Index	Derived variable categorizing respondents as ‘active’, ‘moderately active’ or ‘inactive’ based on the calculated total daily energy expenditure (DEE) in $kcal \cdot kg^{-1} \cdot day^{-1}$ (KKD) The average DEE was calculated based on the reported frequency and duration per session and a fixed assigned metabolic equivalent (MET) value associated with each reported type of activity.	• *Inactive (< 1.5 KKD)* • Moderate (1.5–3.0 KKD) • Active (≥ 3.0 KKD)

* Reference category is *italicized*

4.2.3.3 Control Variables

The control variables included in the analysis were chosen a priori based upon the Andersen-Newman model of health services utilization.[52,53] Within this framework, individual determinants of health services utilization are categorized as 'predisposing', 'enabling' and 'need' factors, all of which are thought to influence the decision to seek medical care.[53] Selected environmental factors, including those related to the health system, the external environment, and the community, were also included, given their influence on health services utilization.[54] Detailed descriptions and coding/recoding information for the control variables is included in Appendix B-3. All known predisposing, enabling and need factors associated with health services utilization that were available in the CCHS Cycle 3.1 were included as control variables in all regression analyses.

Predisposing factors

Predisposing factors refer to the socio-cultural characteristics of individuals that exist prior to illness.[53] In addition to age and sex, the following self-reported predisposing factors were included as control variables in the analysis: marital status, education; ethnicity; immigration status.

Enabling Factors

Socio-economic factors such as income as well as accessibility of health care providers and facilities may act to facilitate or impede one's ability to obtain health care services.[53] The following self-reported enabling factors were included as control variables in the analysis: employment status, annual household income, household size, dwelling size, ability to speak English and/or French; and access to a regular family doctor. Given the level of non-response

(>20%) in the income variable, a missing category was included in order to control for systematic differences in this variable.

Need factors

The perceived and/or evaluated need for health services has been found to be the one of the strongest predictors of health services utilization.[53] In the present study, the following self-reported variables were considered as indicators of need: self-rated general health, self-rated mental health, injury in previous 12 months, limitation in activities of daily living (ADLs), body mass index (BMI), the presence of medically diagnosed conditions including: cardiovascular/cerebrovascular disease(heart disease, stroke), hypertension, COPD (emphysema, chronic bronchitis, COPD), asthma, diabetes, cancer (currently or ever), neurological conditions (chronic fatigue syndrome, migraines, Alzheimer's/other dementia, epilepsy), rheumatologic conditions (fibromyalgia, arthritis/rheumatism), back problems, gastro-intestinal disorders (intestinal/stomach ulcers, Crohn's disease/ulcerative colitis/irritable bowel syndrome/bowel incontinence), mood or anxiety disorders, and chronic conditions not otherwise listed and lastly, the number of chronic conditions reported.

Personal lifestyle factors

Behaviours such as smoking, alcohol consumption, diet and physical activity may influence health services utilization through their association with health status. Several personal lifestyle factors beyond LTPA were included in the analysis, including smoking status, exposure to 2nd hand smoke, and alcohol consumption. Three variables related to non-LTPA were also included as control variables: variables describing walking and cycling for transportation and a variable describing respondents' usual daily activities or work habits, outside of their LTPA.

Environmental factors

Environmental factors include general characteristics of the healthcare delivery system, external environmental factors reflecting the economic and political climate, level of societal stress and violence and the prevailing societal norms and community-level enabling variables, such as physician availability and other community attributes, that influence one's ability to obtain services.[54] Only two environmental variables, province of residence and urban-rural location, were available and thus considered in the analysis.

4.2.4 Statistical Analyses

All analyses were carried out at the Saskatchewan Research Data Centre using SPSS 17.0 (SPSS Inc., Chicago, IL) and STATA 10 (Statacorp LP, College Station, TX). To account for unequal probability of selection in the CCHS Cycle 3.1 due to the complex sampling design, sample weights were applied in all analyses in order to obtain population-based estimates.[46] Unless otherwise indicated, a significance level of $p<0.05$ was applied.

In order to describe the characteristics of the study population, frequencies or means ± SD were determined as appropriate for all independent variables of interest. The sample was stratified on the basis of age and PA level into three age groups (50 – 64 years, 65 – 79 years, 80 years and older) and three activity levels (active, moderately active and inactive). The decision to stratify by age was made *a priori*, in recognition of the considerable heterogeneity within the demographic subgroups of the older adult population relative to PA, health and health services utilization.[20,21,34,55]

Dependent variables were assessed separately for each age group. The distributions of all dependent variables were compared between PA groups using chi square and ANOVA for categorical and continuous variables, respectively. When the assumptions for these tests were not met, the Fisher's Exact test, the Mann-Whitney test or the Kruskal Wallis test were used, as appropriate.

General linear modeling procedures were employed in order to assess the association between LTPA and each dependent variable. Multiple logistic regression models were used to obtain odds ratios (OR) describing the association between LTPA and the dichotomous variables indicating use or non-use of physician services as well as those indicating high use of physician services. Negative binomial (NB) regression modeling was used to obtain incident rate ratios (IRR) in order to assess the relationship between LTPA and the annual number of physician consultations.[26,34] Count data models such as NB regression models are often employed in analyzing health services data in order to deal with issues of non-normal distribution and over-dispersion that are characteristic of count data.[26,56] The association between LTPA and overnight hospitalizations and the total number of nights spent in hospital was assessed using ORs and IRRs obtained through multiple logistic regression and NB regression techniques, respectively. In all analyses, the reference group was the inactive category.

Bootstrap re-sampling procedures were used to produce corrected standard errors to calculate confidence intervals and to test for statistical significance. This technique is recommended for estimating sample variances in surveys with a large number of strata and multiple primary sampling units per stratum where exact design effects are not known.[57] A bootstrap macro specific to the CCHS Cycle 3.1 was provided by Statistics Canada.

4.3 RESULTS

4.3.1 Descriptive Analyses

Information pertaining to the socio-demographic, health and lifestyle characteristics of respondents are presented by age group and PA level in Table 4.2. In the 50 to 64 and 65 to 79 year age group, the majority of the population was married and had completed high school. Most respondents in the oldest age group were not married and although the majority had completed high school, this age group was more evenly split across education levels. Across all age groups, less than 5% of the population self-identified as Aboriginal. The vast majority were born in Canada and lived in urban areas (>66% and ≥79%; respectively).

With regards to income, more than half of older adults under the age of 65 reported annual household incomes greater than $30,000; however fewer than 30% respondents over the age of 65 reported annual incomes exceeding $30,000 per year. Notably, the proportion of respondents with missing data in this variable increased with increasing age. Approximately two-thirds of the population aged 50 to 64 and 10% of those aged 65 to 79 years were employed. The majority of respondents under the age of 80 reported living in a household with two or more people while close to half of those 80 years and older lived alone.

The vast majority (>90%) of respondents reported having a regular family doctor and this increased with increasing age. With the exception of inactive respondents in the two oldest age groups, more than 80% of respondents reported their general health to be excellent, very good or good; more than 90% of respondents, without exception, reported their mental health to be at the same level. At the same time, close to 80% of respondents under the age of 65 and 90% of those over age 65 reported having at least one chronic condition. In each age group, the proportion of active older adults reporting no chronic conditions was higher than in the inactive and moderately active groups. The most prevalent chronic conditions were arthritis/rheumatologic conditions (24.5% - 56%), hypertension (21% - 49%), back problems (17% - 26%), and cardio/cerebrovascular conditions (6% - 31%). The prevalence of most conditions was higher in older age groups and lower with increasing PA. One notable exception was in the case of mood/anxiety disorders, where the prevalence was lower in the older age groups compared to the youngest age group.

With regards to personal health practices, the vast majority of respondents (>75%) were non-smokers or former smokers and most (>65%) reported that they did not consume alcohol. Except for inactive respondents in the oldest age group, at least 50% of respondents reported spending, on average, more than 1 hour daily walking to work and/or to complete errands while fewer than 5% reported cycling daily to do the same. The majority of respondents (40% - 59%) reported standing or walking as their usual or typical daily activity. In each age group, the proportion of respondents reporting their usual activity as sitting was lower as the activity level increased.

Table 4.2: Population characteristics, stratified by age group and activity level (N=56 652)[a]

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive (*n*=15 393)	Mod. Active (*n*=7 882)	Active (*n*=6 639)	Inactive (*n*=11 109)	Mod. Active (*n*=5 027)	Active (*n*=4 047)	Inactive (*n*=4 772)	Mod. Active (*n*=1 101)	Active (*n*=682)
Predisposing factors									
Age (mean±SD)	56.2±4.2	56.4±4.3	56.5±4.2	71.5±4.3	70. 9±4.2	70.6±3.9	84.2±3.6	83.2±3.2	83.0±2.9
	%	%	%	%	%	%	%	%	%
Gender									
Male	49.3	47.9	52.6	41.0	47.4	57.8	31.0	41.4	52.9
Female	50.7	52.1	47.4	59.0	52.6	42.2	69.0	58.6	47.1
Marital status									
Married	76.0	78.9	79.5	64.8	69.6	72.5	37.0	41.1	53.5
Not married/Missing	24.0	21.1	20.5	35.2	30.4	27.5	63.0	58.9	46.5
Education									
Completed secondary	76.4	84.4	85.6	52.3	63.4	67.1	44.6	55.1	59.1
< Secondary	20.7	13.2	12.2	43.3	33.9	29.7	49.0	40.4	36.5
Missing	2.9	2.3	2.2	4.4	2.7	3.2	6.4	4.5	4.4
Ethnicity									
Aboriginal/Missing[b]	4.4	3.7	4.0	4.7	3.0	3.3	5.0	4.5	3.7
Non-Aboriginal	95.6	96.3	96.0	95.3	97.0	96.7	95.0	95.5	96.3
Immigration									
Non-immigrant	74.4	76.7	73.8	73.7	69.5	68.2	73.6	70.9	69.9
Immigrant	23.4	21.1	24.3	22.8	28.3	29.3	21.5	26.2	27.4
Missing	2.2	2.2	1.9	3.5	2.2	2.5	4.9	2.9	2.7

[a] All comparisons across age and activity groups were statistically significant ($p<0.05$)

[b] Aboriginal and missing categories combined for purposes of disclosure control due to small cell numbers

Table 4.2[a] continued

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive (*n*=15 393)	Mod. Active (*n*=7 882)	Active (*n*=6 639)	Inactive (*n*=11 109)	Mod. Active (*n*=5 027)	Active (*n*=4 047)	Inactive (*n*=4 772)	Mod. Active (*n*=1 101)	Active (*n*=682)
Enabling Factors	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Household income									
< $15,000	5.8	3.8	4.1	9.1	7.2	5.7	14.4	9.4	9.9
$15,000 – $29,999	29.4	24.0	23.4	49.4	47.5	47.5	45.4	44.4	44.2
≥ $30,000	50.0	59.4	59.7	19.8	27.5	27.1	12.0	20.4	23.0
Missing	14.7	12.7	12.8	21.7	17.8	19.7	28.3	25.8	22.9
Employment status									
Not Employed	30.4	32.7	37.3	85.6	89.2	87.7	100	100	100
Employed	67.2	65.0	60.7	11.7	9.1	10.1			
Missing	2.4	2.3	2.0	2.6	1.7	2.2			
Speaks English/French									
Yes	96.7	97.4	97.4	94.1	94.7	95.5	91.9	94.8	94.9
No	1.1	0.6	0.7	2.7	3.5	2.2	3.7	2.1	2.6
Missing	2.2	2.0	1.9	3.2	1.8	2.3	4.4	3.0	2.6
Has regular family doctor									
Yes	90.3	91.8	90.9	94.6	96.1	93.9	96.2	96.6	95.4
No/Missing	9.7	8.2	9.1	5.4	3.9	6.1	3.8	3.4	4.6
Household Size									
1 person	14.8	13.8	14.3	27.9	23.7	22.8	51.0	48.6	40.6
2 people	48.3	51.6	51.3	58.7	62.4	66.2	39.4	41.0	50.7
3 or more people	36.9	34.6	34.4	13.5	13.9	11.0	9.6	10.4	8.6
Dwelling Size									
< 3 bedrooms	27.4	24.3	23.4	38.4	36.2	34.5	50.2	48.1	45.6
3 bedrooms	42.5	42.9	41.8	39.1	40.0	41.5	29.8	30.3	32.7
>3 bedrooms	26.5	29.7	31.8	17.4	20.7	20.3	12.0	15.4	18.5
Missing	3.6	3.0	3.0	5.0	3.1	3.7	7.9	6.1	3.3

[a] All comparisons across age and activity groups were statistically significant (*p*<0.05)

Table 4.2[a] continued

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive (*n*=15 393)	Mod. Active (*n*=7 882)	Active (*n*=6 639)	Inactive (*n*=11 109)	Mod. Active (*n*=5 027)	Active (*n*=4 047)	Inactive (*n*=4 772)	Mod. Active (*n*=1 101)	Active (*n*=682)
Need factors	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Self-rated general health									
Excellent/very good/good	80.8	88.8	91.9	69.8	83.6	88.0	63.5	81.2	82.5
Fair/poor/Missing	19.2	11.2	8.1	30.2	16.4	12.0	36.5	18.8	17.5
Self-rated mental health									
Excellent/very good/good	93.1	95.2	96.7	93.7	96.6	97.0	91.0	95.9	95.3
Fair/poor/Missing	6.9	4.8	3.3	6.3	3.4	3.0	9.0	4.1	4.7
# of chronic conditions									
None/Missing	20.3	20.0	23.3	10.1	10.7	14.1	7.7	10.9	13.1
1 condition	25.1	28.9	30.3	17.4	21.3	23.9	13.7	19.3	20.1
2 conditions	21.7	22.0	22.3	21.8	24.9	24.8	20.1	23.8	26.7
3 conditions	23.8	21.9	17.7	37.1	30.7	26.6	41.4	34.3	26.5
≥ 4 conditions	9.0	7.2	6.3	13.6	12.5	10.6	17.1	11.7	13.7
Hypertension									
Yes	28.1	25.6	21.1	46.0	41.9	36.5	49.3	44.2	39.0
No/Missing	71.9	74.4	78.9	54.0	58.1	63.5	50.7	55.8	61.0
Cardio/Cerebrovascular									
Yes	8.0	7.0	5.8	21.1	16.5	15.0	30.9	23.6	19.7
No/Missing	92.0	93.0	94.2	78.9	83.5	85.0	69.1	76.4	80.3
COPD									
Yes	5.3	3.6	2.8	8.8	5.3	5.2	9.8	6.3	5.6
No/Missing	94.7	96.4	97.2	91.2	94.7	94.8	90.2	93.7	94.4
Asthma									
Yes	7.8	6.9	6.0	8.5	7.0	6.2	7.0	5.1	6.4
No/Missing	92.2	93.1	94.0	91.5	93.0	93.8	93.0	94.9	93.6
Diabetes									
Yes	9.7	6.9	6.2	17.2	12.3	11.1	14.7	9.5	9.6
No/Missing	90.3	93.1	93.8	82.8	87.7	88.9	85.3	90.5	90.4

[a] All comparisons across age and activity groups were statistically significant (p<0.05)

Table 4.2[a] continued

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive (*n*=15 393)	Mod. Active (*n*=7 882)	Active (*n*=6 639)	Inactive (*n*=11 109)	Mod. Active (*n*=5 027)	Active (*n*=4 047)	Inactive (*n*=4 772)	Mod. Active (*n*=1 101)	Active (*n*=682)
Need factors continued	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Cancer									
Yes	8.8	8.0	8.4	16.0	15.4	16.3	20.7	20.2	19.5
No/Missing	91.2	92.0	91.6	84.0	84.6	83.7	79.3	79.8	80.5
Neurological									
Yes	13.0	11.3	9.3	7.8	6.7	4.6	7.1	4.6	4.7
No/Missing	87.0	88.7	90.7	92.2	93.3	95.4	92.9	95.4	95.3
Arthritis/Rheumatologic									
Yes	30.3	27.1	24.5	47.7	42.8	37.8	56.1	45.5	41.1
No/Missing	69.7	72.9	75.5	52.3	57.2	62.2	43.9	54.5	58.9
Back problems									
Yes	26.3	24.1	21.4	25.0	22.7	18.7	25.7	21.9	17.3
No/Missing	73.7	75.9	78.6	75.0	77.3	81.3	74.3	78.1	82.7
GI conditions									
Yes	9.2	6.9	6.8	10.1	8.4	6.6	11.4	8.0	7.1
No/Missing	90.8	93.1	93.2	89.9	91.6	93.4	88.6	92.0	92.9
Mood/anxiety disorders									
Yes	10.6	9.1	7.2	7.8	5.8	4.0	5.2	3.7	3.6
No/Missing	89.4	90.9	92.8	92.2	94.2	96.0	94.8	96.3	96.4
Other chronic condition									
Yes	48.3	50.6	47.9	61.3	57.9	54.7	67.3	61.9	59.8
No/Missing	51.7	49.4	52.1	38.7	42.1	45.3	32.7	38.1	40.2
Body mass index									
$\geq$ 30.0 kg/m^2									
25.0 – 29.9 kg/m^2									
<25.0 kg/m^2									

[a] All comparisons across age and activity groups were statistically significant (p<0.05)

Table 4.2[a] continued

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive	Mod. Active	Active	Inactive	Mod. Active	Active	Inactive	Mod. Active	Active
	(*n*=15 393)	(*n*=7 882)	(*n*=6 639)	(*n*=11 109)	(*n*=5 027)	(*n*=4 047)	(*n*=4 772)	(*n*=1 101)	(*n*=682)
Need factors continued	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Injury Status									
No	78.0	77.0	75.5	84.5	85.1	83.8	84.3	86.2	87.6
Yes	19.8	20.9	22.7	12.1	13.0	13.8	10.9	11.1	10.0
Missing	2.2	2.1		3.4	1.9	2.4	4.9	2.7	2.4
Limitations in ADLs									
No/Missing	59.6	65.8	71.2	46.4	58.0	64.6	28.7	42.9	49.6
Yes	40.4	34.2	28.8	53.6	42.0	35.4	71.3	57.1	50.4
Personal Health Practices									
Smoking status									
Non-smoker/Missing	27.6	28.0	27.8	33.6	35.2	30.5	43.9	41.1	32.2
Former smoker	48.1	55.2	55.5	51.8	55.7	60.6	49.3	53.7	63.7
Current smoker	24.3	16.8	16.7	14.6	9.1	8.9	6.7	5.1	4.1
Exposure to 2nd Hand Smoke									
No/Missing	74.0	78.2	81.1	83.7	86.8	87.0	91.7	93.6	91.0
Yes	26.0	21.8	18.9	16.3	13.2	13.0	8.3	6.4	9.0
Alcohol consumption									
No	69.7	64.1	59.7	77.0	69.5	63.8	83.7	79.3	73.1
Yes	26.7	32.3	36.9	19.0	27.5	32.3	12.4	19.1	22.1
Missing	3.6	3.5	3.4	3.9	2.9	3.9	3.9	1.6	4.8
Typical daily PA									
Usually sit	27.5	21.6	17.0	30.4	12.3	7.4	48.1	21.5	11.0
Stand or walk	43.2	46.1	48.0	48.2	58.1	53.8	40.9	56.9	58.9
Lift light/Heavy loads	28.5	31.7	34.6	20.1	28.7	38.0	9.0	20.5	29.3
Missing	0.8	0.6	0.4	1.3	0.9	0.9	2.1	1.1	0.8

[a] All comparisons across age and activity groups were statistically significant (p<0.05)

Table 4.2[a] continued

	Age Group								
	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive	Mod. Active	Active	Inactive	Mod. Active	Active	Inactive	Mod. Active	Active
	(*n*=15 393)	(*n*=7 882)	(*n*=6 639)	(*n*=11 109)	(*n*=5 027)	(*n*=4 047)	(*n*=4 772)	(*n*=1 101)	(*n*=682)
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Personal Health Practices continued									
Active transportation to work/errands									
Time spent walking									
None	34.3	30.0	29.0	35.6	26.2	28.3	45.7	27.0	30.9
< 1hour/day	13.1	11.5	10.1	12.6	11.7	7.9	12.7	13.1	8.9
> 1hour/day	51.2	56.9	59.9	49.5	60.0	62.0	37.4	55.9	57.2
Missing	1.4	1.6	1.1	2.3	2.1	1.8	4.2	3.9	3.0
Bike to work/errands									
No/Missing	97.8	96.0	90.8	98.8	97.1	94.3	99.0	98.3	97.1
Yes	2.2	4.0	9.2	1.2	2.9	5.7	1.0	1.7	2.9
Environmental factors									
Province									
Ontario	36.4	35.6	37.5	37.2	39.4	40.6	36.9	38.3	34.4
Quebec	27.4	25.4	24.8	26.6	24.3	25.1	24.0	15.9	19.0
British Columbia	11.3	15.2	17.2	11.0	16.2	16.9	12.3	20.6	25.2
Alberta	9.1	9.6	8.7	8.1	8.2	6.8	7.8	11.7	8.7
Saskatchewan	2.9	2.5	2.5	3.4	2.9	2.9	5.0	4.0	4.1
Manitoba	3.7	3.4	2.9	4.0	3.1	2.3	4.8	4.1	3.8
Rest of Canada	9.2	8.3	6.4	9.8	5.9	5.3	9.3	5.3	4.8
Residence									
Urban	79.0	79.6	79.4	79.9	83.8	79.9	84.3	88.8	84.3
Rural	21.0	20.4	20.6	20.1	16.2	20.1	15.7	11.2	15.7

[a] All comparisons across age and activity groups were statistically significant ($p<0.05$)

Descriptive data for all health service utilization variables, stratified by age group and LTPA level are presented in Table 4.3. In all age groups, the number GP and specialist consultations differed significantly (*p*<.001) between each LTPA level. With the exception of specialist consultations in the oldest age groups, the moderately active group reported fewer GP and specialist consultations than the inactive group and the active group reported fewer GP and specialist consultations than either the moderately active or the inactive group. The majority of respondents reported having between 1 and 4 GP consultations and no specialist consultations in the previous year. In the youngest age group, between 16.5% and 22% of respondents had no visits to their GP in the previous year while in the oldest age group, fewer than 13% had no visits. Across all age groups, between 29% and 36% of respondents reported at least one contact with a specialist physician in the previous 12 months.

Across all age groups, fewer than 20% of individuals had been hospitalized in the previous 12-month period. The proportion of respondents who had been hospitalized was highest in the inactive group and lowest in the active group regardless of age group. The number of nights spent in hospital differed significantly (*p*<.001) according to LTPA level, with the number of nights in hospital decreasing with increasing LTPA, across all age groups.

Table 4.3: Health services utilization, stratified by age group and PA level

	50 – 64 Yrs. (*n*=29 914)			65 – 79 Yrs. (*n*=20 183)			80 Yrs. and older (*n*=6 555)		
	Inactive (*n*=15 393)	Mod. Active (*n*=7 882)	Active (*n*=6 639)	Inactive (*n*=11 109)	Mod. Active (*n*=5 027)	Active (*n*=4 047)	Inactive (*n*=4 772)	Mod. Active (*n*=1 101)	Active (*n*=682)
*GP Consultations**									
Mean (SD)	3.5 (5.3)	3.1 (4.7)	2.7 (4.2)	4.2 (5.2)	3.6 (3.9)	3.3 (4.4)	5.4 (7.6)	4.4 (4.7)	3.9 (3.8)
	%	%	%	%	%	%	%	%	%
None	17.9	16.3	21.8	12.7	11.4	14.8	9.7	12.6	11.3
1 consultation	20.2	23.4	23.8	14.4	16.9	20.8	11.0	14.4	16.4
2 to 4 consultations	41.0	42.4	40.0	43.9	49.1	45.7	41.5	40.8	45.8
5 to 8 consultations	11.8	11.3	9.2	16.1	13.5	11.7	19.0	17.3	16.0
9 or more consultations	9.1	6.6	5.1	12.9	9.0	7.0	18.9	14.9	10.5
†*Specialist Consultations**									
Mean (SD)	1.1 (3.8)	1.0 (4.3)	0.8 (2.5)	1.0 (3.2)	0.8 (2.1)	0.8 (1.9)	0.9 (2.7)	0.8 (2.4)	0.8 (2.2)
	%	%	%	%	%	%	%	%	%
None	67.7	69.1	71.0	64.5	65.4	66.1	68.4	65.9	69.6
1 consultation	13.9	13.8	14.5	14.9	16.4	15.8	12.3	15.8	16.8
2 consultations	6.9	7.4	5.8	8.6	9.2	9.0	7.8	9.6	3.5
3 or more consultations	11.5	9.7	8.7	12.0	9.0	9.1	11.4	8.6	10.1
*Hospital admission in past year**									
Yes	7.8	6.1	5.7	14.1	9.9	8.5	19.7	14.4	10.5
No	92.2	93.9	94.3	85.9	90.1	91.5	80.3	85.6	89.5
*Total number of hospital nights**									
Mean (SD)	9.2 (21.2)	9.3 (23.4)	7.2 (16.8)	11.0 (21.2)	9.4 (20.1)	8.0 (17.6)	13.4 (25.8)	10.3 (16.1)	9.7 (12.6)

†Specialist consultations include all specialist physicians except eye specialists
*Within each age group, PA groups were significantly different (p<.001) on all health service utilization variables

4.3.2 Regression Analyses

The results of regression analyses are presented separately for each age group.

4.3.2.1 50 to 64 Year Age Group

The results of the regression analyses pertaining to the 50 to 64 year age group are presented in Table 4.4. After adjusting for other factors related to health services utilization, active individuals in this youngest age group were 27% less likely than their inactive counterparts to have had contact with a GP in the 12-month study period (OR=0.73; $p<.001$). Being physically active was also associated with 8% fewer GP consultations over the 12-month study period (IRR=0.92; $p<.01$). Moderately active and active respondents were 7% and 16% less likely to be high users of GP services, respectively; however, these results were not statistically significant.

In relation to the use of specialist physician services, moderately active and active 50 to 64 year olds were as likely as their inactive counterparts to have at least one contact with a specialist physician and were no more or less likely to be a high user of specialist services. Lastly, LTPA was not associated with higher rates of specialist physician contacts during the 12 month study period in this age group.

Lastly, after adjusting for other determinants of hospital services utilization, moderately active and active 50 to 64 year olds were 8% and 3% less likely, respectively, to have had an overnight hospitalization in the previous 12 months; however, this was not statistically significant. Furthermore, LTPA was not significantly associated with the number of nights spent in hospital across activity level in this age group.

Table 4.4 The association between LTPA and health services utilization in the 50 to 64 year age group. (N=29,914)

-	50 to 64 Year Age Group					
	Unadjusted			Adjusted		
	OR/IRR[a]	(95% C.I.)	Sig	OR/IRR	(95% C.I.)	Sig
GP Services						
At least 1 GP contact						
Moderately Active	1.12	(0.99-1.26)	.061	1.01	(0.88-1.17)	.854
Active	0.78	(0.70-0.88)	<.001	0.73	(0.63-0.84)	<.001
Number of GP Consultations[a]						
Moderately Active	0.88	(0.83-0.94)	<.001	0.97	(0.92-1.03)	.308
Active	0.78	(0.74-0.84)	<.001	0.92	(0.87-0.97)	.002
High Use of GP Services						
Moderately Active	0.72	(0.62-0.84)	<.001	0.93	(0.77-1.12)	.438
Active	0.57	(0.48-0.68)	<.001	0.84	(0.68-1.04)	.118
*Specialist Physician Services**						
At least 1 Specialist contact						
Moderately Active	0.94	(0.86-1.02)	.138	0.99	(0.89-1.09)	.792
Active	0.85	(0.77-0.95)	.002	0.99	(0.87-1.12)	.882
Number of Specialist Consultations[a]						
Moderately Active	0.93	(0.80-1.08)	.339	1.01	(0.90-1.13)	.858
Active	0.77	(0.65-0.90)	.002	1.04	(0.90-1.21)	.557
High Use of Specialist Services						
Moderately Active	0.83	(0.72-0.95)	.009	0.94	(0.80-1.11)	.461
Active	0.74	(0.62-0.88)	.001	1.01	(0.82-1.26)	.891
Hospital Services†						
Overnight Hospitalization						
Moderately Active	0.77	(0.65-0.90)	.001	0.92	(0.76-1.12)	.416
Active	0.71	(0.58-0.86)	.001	0.97	(0.77-1.23)	.822
Number of nights in hospital[a]						
Moderately Active	1.01	(0.69-1.49)	.940	1.15	(0.94-1.43)	.181
Active	0.78	(0.49-1.25)	.303	1.03	(0.80-1.33)	.816

[a] Indicates the estimate is an incidence rate ratio (IRR).

Note: Analyses adjusted for (reference category in italics): Age; sex (*male*/female); marital status (married – *yes*/no); education (graduated secondary – *yes*/no); ethnicity (*Non-Aboriginal*/Aboriginal); employment status (employed –*no*/yes); household size (*1*, 2, 3 or more people); dwelling size (*< 3 bedrooms*, 3bedrooms, > 3 bedrooms); immigration status (*non-immigrant*, immigrant); injury in previous 12 months (*no*/yes); limitation in ADLs (*no*/yes); smoking status (*never smoked*/former smoker/non-smoker); exposed to 2[nd] hand smoke (*no*/yes); alcohol consumption (*No*/Yes); BMI (*< 25.0 kg·m²*/25.0-29.9 kg·m²/≥ 30 kg·m² or greater); time spent walking to work or to do errands (*none*/ <1 hour/ ≥1hour); cycling to work or to do errands (*no*/yes); typical daily activity level (*usually sit*/stand or walk/lift light and/or heavy loads); annual household income (*<$15,000*; $15,000-$29,999; ≥ $30,000; missing); province (*ON*, MB, AB, BC, SK, QC, NB, NS, PE, NL, YT/NT/NU); urban-rural classification (*urban*/rural); language (able to speak English and/or French – *yes*/no); has regular family doctor (*yes*/no); self-rated general health (*excellent/very good/good*; fair/poor); self-rated mental health (*excellent/very good/good*; fair/poor); diagnosed with: hypertension; cardiovascular disease (including stroke); COPD; asthma; diabetes; cancer; neurological conditions; rheumatologic; back problems; gastrointestinal disorders; mood/anxiety disorders; other chronic condition (*no*/yes for each); number of chronic conditions (*none*/1 condition/2 conditions/3 conditions/4 or more conditions).
* Analyses of specialist services also adjusted for number of GP consults
† Analyses of hospital services also adjusted for specialist physician consults (yes/*no*)

4.3.2.2 65 to 79 Year Age Group

The results of the regression analyses pertaining to the 65 to 79 year age group are presented in Table 4.5. In this age group, no significant associations were found between LTPA and the use of GP services. Moderately active or active individuals had 4% fewer GP consultations over the 12-month study period (IRR=0.96) and were 6% less likely to be high users of GP services than their inactive counterparts.

A somewhat different pattern emerged in the results pertaining to the use of specialist physician services. Although not statistically significant, moderately active and active 65 to 79 year olds were 3% and 13% more likely, respectively, than their inactive counterparts to have had at least one contact with a specialist physician; however, they were 14% and 5% less likely, respectively, to be high users of specialist services.

Lastly, after adjusting for other determinants of hospital services utilization, active 65 to 79 year olds were 18% less likely to have had an overnight hospitalization in the previous 12 months (OR=0.82, p=.032). Although PA was associated with between 3% and 7% fewer nights in hospital in this age group, this was not statistically significant.

Table 4.5 The association between LTPA and health services utilization in the 65 to 79 year age group (N=20 183)

	65 to 79 Year Age Group					
	Unadjusted			Adjusted		
	OR/IRR[a]	(95% C.I.)	Sig	OR/IRR	(95% C.I.)	Sig
GP Services						
At least 1 GP contact						
Moderately Active	1.13	(0.97-1.32)	.122	1.13	(0.95-1.34)	.173
Active	0.84	(0.72-0.97)	.016	0.99	(0.82-1.21)	.959
Number of GP Consultations[a]						
Moderately Active	0.86	(0.81-0.90)	<.001	0.96	(0.92-1.01)	.123
Active	0.77	(0.72-0.82)	<.001	0.96	(0.90-1.01)	.122
High Use of GP Services						
Moderately Active	0.68	(0.58-0.79)	<.001	0.94	(0.78-1.13)	.494
Active	0.50	(0.42-0.59)	<.001	0.85	(0.70-1.03)	.105
*Specialist Physician Services**						
At least 1 Specialist contact						
Moderately Active	0.96	(0.87-1.06)	.427	1.03	(0.90-1.18)	.658
Active	0.93	(0.83-1.04)	.217	1.13	(0.98-1.31)	.098
Number of Specialist Consultations[a]						
Moderately Active	0.81	(0.73-0.91)	<.001	1.02	(0.90-1.15)	.780
Active	0.80	(0.71-0.90)	<.001	1.02	(0.91-1.15)	.709
High Use of Specialist Services						
Moderately Active	0.73	(0.63-0.84)	<.001	0.86	(0.71-1.03)	.101
Active	0.73	(0.61-0.88)	.001	0.95	(0.76-1.18)	.645
Hospital Services[†]						
Overnight Hospitalization						
Moderately Active	0.67	(0.57-0.78)	<.001	0.90	(0.76-1.07)	.229
Active	0.57	(0.49-0.66)	<.001	0.82	(0.68-0.98)	.032
Number of nights in hospital[a]						
Moderately Active	0.85	(0.62-1.17)	.328	0.97	(0.77-1.22)	.795
Active	0.72	(0.52-1.01)	.058	0.93	(0.71-1.22)	.589

[a] Indicates the estimate is an incidence rate ratio (IRR).

Note: Analyses adjusted for (reference category in italics): Age; sex (*male*/female); marital status (married – *yes*/no); education (graduated secondary – *yes*/no); ethnicity (*Non-Aboriginal*/Aboriginal); employment status (employed –*no*/yes); household size (*1*, 2, 3 or more people); dwelling size *(< 3 bedrooms*, 3bedrooms, > 3 bedrooms); immigration status (*non-immigrant*, immigrant); injury in previous 12 months (*no*/yes); limitation in ADLs (*no*/yes); smoking status (*never smoked*/former smoker/non-smoker); exposed to 2[nd] hand smoke (*no*/yes); alcohol consumption (*No*/Yes); BMI *(< 25.0 kg·m^2*/25.0-29.9 kg·m^2/≥ 30 kg·m^2 or greater); time spent walking to work or to do errands (*none*/ <1 hour/ ≥1hour); cycling to work or to do errands (*no*/yes); typical daily activity level (*usually sit*/stand or walk/lift light and/or heavy loads); annual household income *(<$15,000*; $15,000-$29,999; ≥ $30,000; missing); province (*ON*, MB, AB, BC, SK, QC, NB, NS, PE, NL, YT/NT/NU); urban-rural classification (*urban*/rural); language (able to speak English and/or French – *yes*/no); has regular family doctor (*yes*/no); self-rated general health (*excellent/very good/good*; fair/poor); self-rated mental health (*excellent/very good/good*; fair/poor); diagnosed with: hypertension; cardiovascular disease (including stroke); COPD; asthma; diabetes; cancer; neurological conditions; rheumatologic; back problems; gastrointestinal disorders; mood/anxiety disorders; other chronic condition (*no*/yes for each); number of chronic conditions (*none*/1 condition/2 conditions/3 conditions/4 or more conditions).

* Analyses of specialist services also adjusted for number of GP consults
[†] Analyses of hospital services also adjusted for specialist physician consults (yes/*no*)

4.3.2.3 80 Years & Older

The results of the regression analyses pertaining to the 80 years and older age group are presented in Table 4.6. In this age group, no significant associations were found between LTPA and the use of GP services. Moderately active or active individuals had 7-10% fewer GP consultations over the 12-month study period (IRR=0.93 and IRR=0.90, respectively). When considering high use of GP services, active individuals were 5% less likely to be high users of GP services than their inactive counterparts (OR=0.95; $p>.05$).

In this age group, LTPA was not significantly associated with the use of specialist physician services. However, moderately active and active individuals aged 80 years and older were 10% and 26% more likely, respectively, than their inactive counterparts to have had at least one contact with a specialist physician ($p=.068$ and $p=.570$, respectively). Active individuals also reported 6% more specialist visits ($p=.661$) over the 12 study period and were 20% more likely to be high users of specialist services ($p=.448$) than their inactive counterparts. In contrast, moderate activity was negatively associated with high use of specialist services (OR=0.72; $p=.172$).

The use of hospital services was not significantly associated with LTPA in the 80 year and older age group; however, moderately active and active individuals were 11% and 32% less likely, respectively, to report being hospitalized during the 12 month study period ($p=.483$ and $p=.087$; respectively). Among those reporting a hospitalization, active individuals spent approximately 20% more nights in hospital, although this, too, was not statistically significant ($p=.401$).

Table 4.6 The association between LTPA and health services utilization in the 80 year and older age group (N=6 555)

	80 Years & Older Age Group					
	Unadjusted			Adjusted*		
	OR/IRR[a]	(95% C.I.)	Sig	OR/IRR	(95% C.I.)	Sig
GP Services						
At least 1 GP contact						
Moderately Active	0.74	(0.55-1.01)	.058	0.77	(0.52-1.15)	.199
Active	0.84	(0.60-1.19)	.324	1.26	(0.78-2.03)	.340
Number of GP Consultations[a]						
Moderately Active	0.82	(0.74-0.92)	<.001	0.93	(0.83-1.04)	.225
Active	0.72	(0.65-0.81)	<.001	0.90	(0.79-1.02)	.113
High Use of GP Services						
Moderately Active	0.74	(0.58-0.96)	.022	1.01	(0.74-1.40)	.934
Active	0.55	(0.40-0.75)	<.001	0.95	(0.64-1.40)	.784
*Specialist Physician Services**						
At least 1 Specialist contact						
Moderately Active	1.12	(0.92-1.37)	.263	1.26	(0.98-1.61)	.068
Active	0.95	(0.74-1.21)	.660	1.10	(0.80-1.50)	.570
Number of Specialist Consultations[a]						
Moderately Active	0.91	(0.69-1.20)	.516	0.98	(0.80-1.21)	.865
Active	0.91	(0.68-1.21)	.506	1.06	(0.81-1.40)	.661
High Use of Specialist Services						
Moderately Active	0.73	(0.49-1.11)	.139	0.72	(0.45-1.15)	.172
Active	0.87	(0.61-1.25)	.457	1.20	(0.75-1.91)	.448
Hospital Services[†]						
Overnight Hospitalization						
Moderately Active	0.69	(0.53-0.89)	.004	0.89	(0.65-1.22)	.483
Active	0.48	(0.34-0.67)	<.001	0.68	(0.43-1.06)	.087
Number of nights in hospital[a]						
Moderately Active	0.77	(0.55-1.08)	.132	0.99	(0.69-1.43)	.966
Active	0.72	(0.48-1.09)	.119	1.19	(0.79-1.79)	.401

[a] Indicates the estimate is an incidence rate ratio (IRR).

Note: Analyses adjusted for (reference category in italics): Age; sex (*male*/female); marital status (married – *yes*/no); education (graduated secondary – *yes*/no); ethnicity (*Non-Aboriginal*/Aboriginal); employment status (employed –*no*/yes); household size (*1*, 2, 3 or more people); dwelling size *(< 3 bedrooms*, 3bedrooms, > 3 bedrooms); immigration status (*non-immigrant*, immigrant); injury in previous 12 months (*no*/yes); limitation in ADLs (*no*/yes); smoking status (*never smoked*/former smoker/non-smoker); exposed to 2[nd] hand smoke (*no*/yes); alcohol consumption (*no*/yes); BMI *(< 25.0 kg·m²*/25.0-29.9 kg·m²/≥ 30 kg·m² or greater); time spent walking to work or to do errands (*none*/ <1 hour/ ≥1hour); cycling to work or to do errands (*no*/yes); typical daily activity level (*usually sit*/stand or walk/lift light and/or heavy loads); annual household income *(<$15,000*; $15,000-$29,999; ≥ $30,000; missing); province (*ON*, MB, AB, BC, SK, QC, NB, NS, PE, NL, YT/NT/NU); urban-rural classification (*urban*/rural); language (able to speak English and/or French – *yes*/no); has regular family doctor (*yes*/no); self-rated general health (*excellent/very good/good*; fair/poor); self-rated mental health (*excellent/very good/good*; fair/poor); diagnosed with: hypertension; cardiovascular disease (including stroke); COPD; asthma; diabetes; cancer; neurological conditions; rheumatologic; back problems; gastrointestinal disorders; mood/anxiety disorders; other chronic condition (*no/*yes for each); number of chronic conditions (*none*/1 condition/2 conditions/3 conditions/4 or more conditions).

* Analyses of specialist services also adjusted for number of GP consults
[†] Analyses of hospital services also adjusted for specialist physician consults (yes/*no*)

4.3.2.4 Association between typical daily activity and health services utilization

While LTPA was the primary independent variable of interest in this study, typical daily activity was also included as a control variable in the analytical models. Respondents were asked to choose the best description of their usual daily activities or work habits, outside of their LTPA. In all three age groups, significant associations were found between typical daily activity and several of the dependent variables such that a brief presentation of these findings is warranted. These findings are presented in Tables 4.7 and 4.8.

Across all age groups, higher levels of usual activity was associated with lower health services utilization. In the 50 to 64 year old age group, those reporting lifting light or heavy loads had significantly fewer GP consultations and were less likely to use specialist physician services ($p<.05$) compared to those reporting sitting as their typical daily activity. Among 65 to 79 year olds, respondents reporting standing or walking were significantly less likely to be high users of GP services and to use specialist physician services while those reporting lifting light or heavy loads were significantly less likely to have contact with a GP physician, had fewer GP and specialist physician consultations, were less likely be high users of specialist physician services, were less likely to be hospitalized overnight and spent fewer days in hospital than their sitting counterparts ($p <.05$). In the oldest age group, both standing/walking and lifting light or heavy loads were significantly associated with lower levels of GP and physician service utilization compared to those whose typical activity was sitting. Lifting light or heavy loads was also significantly associated with fewer nights in hospital in this age group.

Table 4.7 The association between differing levels of typical daily activity[a] and physician service utilization, stratified by age

	50 to 64 years *n*=29 914			65 to 79 years *n*=20 183			80 years & older *n*=6 555		
	OR/IRR[b]	95% CI	*p*	OR/IRR[b]	95% CI	*p*	OR/IRR[b]	95% CI	*p*
General Physician Services									
At least 1 contact with a GP									
Stand or walk	1.13	(0.96-1.32)	.143	1.19	(0.96-1.47)	.107	0.73	(0.50-1.07)	.104
Lift light/heavy loads	0.90	(0.76-1.06)	.221	0.77	(0.61-0.98)	.030	0.77	(0.46-1.28)	.312
Number of GP Consultation[b]									
Stand or walk	0.97	(0.92-1.02)	.298	0.97	(0.92-1.02)	.239	0.89	(0.81-0.99)	.027
Lift light/heavy loads	0.91	(0.86-0.97)	.002	0.87	(0.82-0.93)	<.001	0.84	(0.73-0.95)	.006
High Use of GP Services									
Stand or walk	0.94	(0.77-1.14)	.522	0.84	(0.71-0.99)	.041	0.67	(0.53-0.85)	.001
Lift light/heavy loads	0.87	(0.70-1.07)	.189	0.74	(0.58-0.94)	.014	0.51	(0.34-0.77)	.001
Specialist Physician Services									
At least 1 contact with a Specialist									
Stand or walk	0.95	(0.85-1.06)	.366	0.88	(0.77-1.00)	.048	0.85	(0.68-1.07)	.169
Lift light/heavy loads	0.85	(0.75-0.97)	.020	0.86	(0.74-1.01)	.065	0.72	(0.52-0.99)	.041
Number of Specialist Consultations[b]									
Stand or walk	0.80	(0.70-0.93)	.002	0.86	(0.75-0.98)	.023	0.76	(0.63-0.92)	.005
Lift light/heavy loads	0.74	(0.64-0.86)	<.001	0.82	(0.71-0.95)	.006	0.66	(0.50-0.88)	.005
High Use of Specialist Services									
Stand or walk	0.83	(0.69-1.01)	.059	0.78	(0.64-0.96)	.017	0.62	(0.46-0.84)	.002
Lift light/heavy loads	0.78	(0.63-0.96)	.018	0.75	(0.60-0.94)	.013	0.58	(0.35-0.97)	.036

[a] Typical daily activity is a 3 level categorical variable describing respondents' usual level of daily activity outside of LTPA. The reference group (not shown in table) is 'usually sit'

[b] Indicates the estimate is an incidence rate ratio (IRR).

Note: Adjusted for (reference category in italics): Age; sex (*male*/female); marital status (married – *yes*/no); education (graduated secondary – *yes*/no); ethnicity (*Non-Aboriginal*/Aboriginal); employment status (employed –*no*/yes); household size (*1*, 2, 3 or more people); dwelling size (*< 3 bedrooms*, 3bedrooms, > 3 bedrooms); immigration status (*non-immigrant*, immigrant); injury in previous 12 months (*no*/yes); limitation in ADLs (*no*/yes); smoking status (*never smoked*/former smoker/non-smoker); exposed to 2nd hand smoke (*no*/yes); alcohol consumption (*< no*/yes); BMI (*< 25.0 kg·m²*/25.0-29.9 kg·m²/≥ 30 kg·m² or greater); time spent walking to work or to do errands (*none*/ <1 hour/ ≥1hour); cycling to work or to do errands (*no*/yes); typical daily activity level (*usually sit*/stand or walk/lift light and/or heavy loads); annual household income (*<$15,000*; $15,000-$29,999; ≥ $30,000; missing); province (*ON*, MB, AB, BC, SK, QC, Other); urban-rural classification (*urban*/rural); language (able to speak English and/or French – *yes*/no); has regular family doctor (*yes*/no); self-rated general health (*excellent/very good/good*; fair/poor); self-rated mental health (*excellent/very good/good*; fair/poor); diagnosed with: hypertension; cardiovascular disease (including stroke); COPD; asthma; diabetes; cancer; neurological conditions; rheumatologic; back problems; gastrointestinal disorders; mood/anxiety disorders; other chronic condition (*no*/yes for each); number of chronic conditions (*none*/1 condition/2 conditions/3 conditions/4 or more conditions); number of GP consults.

Table 4.8 The association between differing levels of typical daily activity[a] and hospital service utilization, stratified by age

	50 to 64 years n=29 914			65 to 79 years n=20 183			80 years & older n=6 555		
	OR/IRR[b]	95% CI	*p*	OR/IRR[b]	95% CI	*p*	OR/IRR[b]	95% CI	*p*
Hospital Services									
Overnight Hospitalization									
Stand or walk	0.93	(0.77-1.12)	.431	0.85	(0.72-1.01)	.060	0.80	(0.62-1.03)	.081
Lift light/heavy loads	0.88	(0.70-1.09)	.243	0.68	(0.56-0.84)	<.001	0.92	(0.64-1.34)	.678
Number of nights in hospital[b]									
Stand or walk	0.78	(0.64-0.94)	.008	0.84	(0.68-1.03)	.095	0.78	(0.59-1.02)	.072
Lift light/heavy loads	0.85	(0.67-1.09)	.204	0.58	(0.45-0.76)	<.001	0.52	(0.36-0.76)	.001

[a] Typical daily activity is a 3 level categorical variable describing respondents' usual level of daily activity outside of LTPA. The reference group (not shown in table) is 'usually sit'

[b] Indicates the estimate is an incidence rate ratio (IRR).

Note: Adjusted for (reference category in italics): Age; sex (*male*/female); marital status (married – *yes*/no); education (graduated secondary – *yes*/no); ethnicity (*Non-Aboriginal*/Aboriginal); employment status (employed –*no*/yes); household size (*1*, 2, 3 or more people); dwelling size *(< 3 bedrooms*, 3bedrooms, > 3 bedrooms); immigration status (*non-immigrant*, immigrant); injury in previous 12 months (*no*/yes); limitation in ADLs (*no*/yes); smoking status (*never smoked*/former smoker/non-smoker); exposed to 2[nd] hand smoke (*no*/yes); alcohol consumption *(no*/yes); BMI *(< 25.0 kg·m²*/25.0-29.9 kg·m²/≥ 30 kg·m² or greater); time spent walking to work or to do errands (*none*/ <1 hour/ ≥1hour); cycling to work or to do errands (*no*/yes); typical daily activity level (*usually sit*/stand or walk/lift light and/or heavy loads); annual household income *(<$15,000*; $15,000-$29,999; ≥ $30,000; missing); province (*ON*, MB, AB, BC, SK, QC, NB, NS, PE, NL, YT/NT/NU); urban-rural classification (*urban*/rural); language (able to speak English and/or French – *yes*/no); has regular family doctor (*yes*/no); self-rated general health (*excellent/very good/good*; fair/poor); self-rated mental health (*excellent/very good/good*; fair/poor); diagnosed with: hypertension; cardiovascular disease (including stroke); COPD; asthma; diabetes; cancer; neurological conditions; rheumatologic; back problems; gastrointestinal disorders; mood/anxiety disorders; other chronic condition (*no/*yes for each); number of chronic conditions (*none*/1 condition/2 conditions/3 conditions/4 or more conditions); specialist physician consults (yes/*no*).

4.4 DISCUSSION

The primary purpose of this study was to examine relationships between LTPA and health services utilization in a nationally (Canadian) representative sample of community-dwelling older adults. Rather than classifying all respondents as one homogeneous group, these relationships were explored separately for 3 age groups: 50 to 64 years, 65 to 79 years and 80 years and older in order to add precision to the existing knowledge base.[20] The descriptive analysis showed that the use of health services generally increased with increasing age, with the exception of consultations with specialist physicians. Between 10% and 22% of respondents reported that they did not consult with a GP physician in the 12-month period – somewhat of a concerning finding from a health perspective, given that it may mean that older adults are going without preventative health care or are having difficulty accessing necessary care. An alternative explanation may be that these individuals received health services from providers other than general practitioners, such as nurse practitioners, naturopathic physicians, chiropractors and physiotherapists; however, this was not assessed in the present study.

The multivariate analyses showed that, in general, LTPA was negatively associated with health services utilization; however, few of the associations were statistically significant. Leisure time PA was significantly associated with lower use of GP physician services in the 50 to 64 year age group, with active individuals 27% less likely to have contact with a GP and reporting 8% fewer GP consultations than their inactive counterparts in the 12-month study period. These findings are consistent with those of Woolcott et al (2010), as well as Wang et al, (2005) who found that regular PA was associated with significantly lower outpatient health care costs in a group of Medicare retirees.[42,58] Similarly, Mitchell et al (2004) also found physician visits to be inversely associated with physical fitness among 6679 men aged 20-79 years.[59] It is, however, important to note that the findings in this area are somewhat equivocal, with several studies reporting no significant association between LTPA and physician visits.[33,40,44] In their population-based study of health-related behaviours in 2311 adults with Type 1 and Type 2 diabetes (mean age = 52.5 and 63.8, respectively), Plotnikoff et al (2010) examined associations between PA and health care utilization (including physician visits and claims) and costs in participants using 4 separate statistical models: (1) a demographic model; (2) a health factor model; (3) a health behavioural model; and (4) a full model including all covariates.[43] In their discussion, Plotnikoff et al (2010) state that their study provides evidence of higher health care utilization and costs in diabetic individuals not meeting minimum PA guidelines, focusing mostly on the health behavioural model and subsidiary one-tailed t-tests performed for each diabetic group. These results show that all five health care utilization and cost variables were significantly lower in T2D individuals meeting current PA guidelines.[43] However, the health behavioral model is adjusted for just two other health behaviours (smoking and diet) while the one-tailed t-tests were unadjusted models. In these models, unobserved differences (such as demographic or health factors) between those individuals meeting and not meeting PA guidelines may partly explain the differences in health care utilization.[25] In the full statistical model, which was adjusted for demographic variables and health factors in addition to other health behaviours, PA was not significantly associated with any health care utilization and cost variable. Therefore, one could argue that this study provides evidence contrary to what its authors assert; however Plotnikoff et al do not address this apparent discrepancy within their discussion.[43]

A significant association was also evident between LTPA and hospital services in the 65 to 79 year age group, where active individuals were 8% less likely to be hospitalized than their inactive counterparts. This partially supports the findings of recent studies by Woolcott et al

(2010) and Sari (2010) which found that LTPA was associated with a decreased likelihood of hospitalization and fewer nights spent in hospital among Canadians aged 65 years and older.[34,42] While LTPA was mostly associated with fewer nights spent in hospital in the present study, these associations were not statistically significant. In the oldest age group, active respondents were actually more likely to report more nights in hospital. One explanation for the different findings may be related to the stratification of the sample of the present study. The studies by Woolcott et al (2010) and Sari (2010) examined CCHS respondents aged 65 years and older as a single study population.[34,42] There is considerable heterogeneity within the older adult population relative to PA, health and health services utilization and it is possible that the stratification of the sample in the present study revealed differences in health services utilization that were obscured in studies which examined the population as a whole.[20]

Although not statistically significant, the results pertaining to the use of specialist services revealed an interesting pattern. In the two oldest age groups, moderately active and active individuals were more likely than their inactive counterparts to have consulted a specialist in the previous 12-months but were less likely, in most cases, to be a high user of specialist services. The only exception was among those 80 years and older, where moderately active individuals were less likely to be high users of specialist services but active individuals were more likely to high users of specialist services. One possible explanation may be that moderately active and active older adults may be more health conscious and/or more health 'literate' and therefore may seek referrals to specialists more frequently than inactive older adults.[60] The data related to specialist physician visits in the CCHS preclude an in-depth analysis of the physician specialty or the reasons underlying visits to specialists, both of which would provide important insights into the utilization of specialist physician services. However, despite its importance from a policy perspective, very few studies have examined the relationship of PA and specialist physician visits separate from visits to other physicians.

The lack of agreement between studies of PA and health services utilization may be due, in part, to considerable variation in sample populations, study design and methods. There is no single 'gold standard' measure of health services utilization and differences between studies in its operationalization make it difficult to form generalizations based on the available literature. Likewise, beyond the use of self-report PA measures, there is very little consistency between studies in how PA is assessed. While most studies examining PA and health services utilization in older adults have used populations aged 65 years and older, the present study used a sample aged 50 years and older. There is significant heterogeneity in health status, PA participation and health services utilization in the older adult population.[20,21,55] As well, there are a number of significant life transitions that typically occur after the age of 50, such as retirement and bereavement, which may have implications for health and health services utilization. Stratifying the data into smaller age groups coinciding with key transition periods and adjusting for age within each age group allows for a more precise analysis and comprehensive examination of the association between LTPA and health services utilization in this diverse population. For example, 50 to 65 years is the age range when many chronic conditions emerge and are diagnosed, hence the increased association with physician visits in this age group. In middle age group (65 to 79 yrs.), chronic conditions may be worsening, resulting in stronger associations with hospitalizations. In both instances, LTPA may play an important role by either delaying the clinical manifestation of certain conditions or slowing progression of the disease process, thereby helping to delay or prevent this type of utilization in younger older adults.

Another notable difference between this analysis and previous studies was the inclusion of a wide-ranging set of control variables. A number of factors influence one's decision to seek medical care and the majority of earlier studies of LTPA and HSU are lacking in their ability to account for other determinants of HSU, be they demographic and socio-economic factors, physical and mental health status and medical co-morbidities, or personal health practices such as smoking and drinking.[26,34,44] It is likely that physical activity affects health care utilization through its relationship with overall health.[44] By including a comprehensive set of health-related control we were also able to account for variations in health that may affect both the level of physical activity and healthcare utilization.[26,34,44]

While LTPA was the primary focus of this study, respondents' typical daily activity outside of LTPA was also examined and appeared to be a stronger predictor of all types of health services utilization, particularly in the two oldest age groups. Even in the youngest age group, typical daily activity was significantly associated with the use of specialist services, where LTPA was not. One possible explanation may be that the typical daily activity variable may provide an indication of sedentary behaviour, which is also associated with the development and chronic health conditions and poorer health status, independent of LTPA.[61] Among younger older adults still in the workforce, the amount of PA accrued during a typical day may exceed that accrued through LTPA due to the number of hours spent working; therefore this type of PA may be a more salient predictor of health services utilization. Another explanation may have to do with how respondents classified their own PA. Older adults typically participate in activities such as housework, gardening and caregiving more frequently than other types of LTPA.[62,63] Given that these types of PA weren't specified in the LTPA questionnaire, respondents may have considered them as part of their usual daily activities, highlighting the importance of implementing measures of PA that are appropriate for older adults, given the types of PA typically reported in this population. It is possible that a more appropriate measure of LTPA may have revealed more significant associations between LTPA and health services utilization. Lastly, among respondents aged 80 years and older, typical daily PA may be reflective of greater mobility and health status and thus, be a stronger predictor of health services utilization.

Prior research in the area of PA and health services utilization has predominantly been focused on individuals in the workplace. This study is among a small few to examine the relationship between PA and health services utilization in community dwelling older Canadians. Furthermore, the focus on both LTPA and typical daily PA is unique and provides new insights into the relationship between PA and health services utilization in the older adult population. Nonetheless, this study has certain limitations that should be considered when interpreting the results. The cross sectional nature of the survey data precludes the inference of causal relationships and one cannot discount the possibility that reverse causality between the outcome measures and one or more independent variables is present. Although participation in PA may result in the maintenance or improvement of health status, which may in turn reduce health services utilization, it is also possible that poor health status may lead to decreased levels of PA and increased levels of health services utilization.[44]

Given the self-reported nature of the data, bias due to inaccurate recall or social desirability remains a possibility, particularly in the PA and health services data. Previous studies have shown that older adults tend to over-report contacts with GP physicians and under-report contacts with medical specialists while recall of events such as hospitalizations appears to be more accurate, perhaps because these events are more highly salient and easily remembered.[64,65] Likewise, there are issues with the use of self-report measures of PA in an older population including vision and hearing impairments or disturbances to cognition and short- or long-term memory.[66] Additional problems may include the ability to accurately report activity intensity, because perceptions of what is “hard” activity or “light” activity depend on the tolerance and fitness level of the individual, both of which decline as a person ages.[66]

A further limitation of this study relates to the CCHS questionnaire itself. In the CCHS Cycle 3.1, self-reported health services utilization is measured for the preceding 12-months while self-reported LTPA is measured for the preceding 3 months. The discrepancy in recall periods may have made it more difficult to identify significant relationships; however, it would be considerably more difficult to accurately recall PA behaviors over a 12 month period compared to a lower frequency event such as health services utilization over the same period.[44] Furthermore, the measurement of LTPA in the CCHS Cycle 3.1 may underestimate older adults' LTPA, particularly in the oldest age group, for at least two reasons: 1) the instrument does not specifically include more prevalent leisure time activities of older adults, such as housekeeping or caregiving and 2) the questionnaire may not be sensitive enough to detect the typically light and brief activity of elderly people.[25,66] Lastly, as health status, physical activity and health services utilization were assessed at a single point in time, one cannot discount the possibility that the relationships were due to factors which prompted physical activity or contributed to low levels of physical activity, resulting in disease, reduced function, and poor mental health. Prospective studies would provide important information regarding the direction of the relationship between physical activity and health services utilization.[12,25,44]

4.6 CONCLUSION

This study adds to a growing body of evidence suggesting that PA leads to lower health services utilization in community dwelling older Canadians; however, it would appear that this relationship may not be as straightforward as suggested by earlier research. Older adults are a very diverse group and this heterogeneity must be considered when examining health services utilization in this population. Although many of the estimates produced in the analyses were not statistically significant, they may have considerable relevance from a clinical perspective. For example, the results showed that moderately active and active respondents in the two oldest age groups were more likely to have at least 1 contact with a specialist and active individuals in the oldest age group appeared to have higher overall utilization of specialist physicians than their inactive or moderately active counterparts. Given that costs associated with specialist physician services are considerably higher than GP physicians, and that most studies do not examine specialist physician utilization separately from other types of physicians, this finding warrants further exploration. It is possible that high levels of LTPA among individuals aged 65 years and older may result in injuries or worsening of conditions such as osteoarthritis, leading to increased health services utilization and costs in this regard. Further studies of the patterns of health services utilization among sedentary, inactive and active older adults would better clarify the potential role of PA as a strategy to decrease health services utilization and costs.

It is possible that interventions aimed at increasing LTPA in this population may result in tangible reductions in health services utilization. The results also suggest that encouraging sedentary and inactive older adults, particularly those over age 65, to maintain or increase their overall daily activity, perhaps simply by reducing time spent in sedentary behaviours, may have an even greater impact on reducing the demand for health services. Given the wide variation in the literature with regards to study populations and methodologies, additional studies, with common outcome measures, appropriate and robust assessments of PA, as well as sedentary behaviour, and adequate controls for confounders, are needed to obtain credible and accurate estimates of the effects of PA. Moreover, prospective longitudinal studies into the causal relationship between PA and health services utilization would provide important information on the potential impact on the health care system of population wide interventions to increase PA participation among older adults.

4.7 LITERATURE CITED

1. United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council of Physical Fitness and Sport. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: US Department of Health and Human Services, Public Health Service, CDC, National Center for Chronic Disease Prevention and Health Promotion; 1996.

2. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: The evidence. *Canadian Medical Association Journal.* 2006;174(6):801-809.

3. Warburton D, Charlesworth S, Ivey A, Nettlefold L, Bredin S. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):39.

4. Paterson DH, Jones GR, Rice CL. Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Canadian Journal of Public Health.* 2007;98 (Suppl 2):S69-S108.

5. Paterson D, Warburton D. Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):38.

6. Katzmarzyk PT, Lear SA. Physical activity for obese individuals: A systematic review of effects on chronic disease risk factors. *Obesity Reviews.* 2012;13(2):95-105.

7. Melzer K, Kayser B, Pichard C. Physical activity: The benefits outweigh the risks. *Current Opinion in Clinical Nutrition & Metabolic Care.* 2004;7(6):641-647.

8. National Institute on Aging, National Institutes of Health, World Health Organization. *Global Health and Aging*. Geneva: World Health Organization; 2011.

9. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair S, Katzmarzyk P. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet.* 2012;380:219-229.

10. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

11. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: An update. *Canadian Journal of Applied Physiology.* 2004;29(1):90-115.

12. Janssen I. Health care costs of physical inactivity in Canadian adults. *Applied Physiology, Nutrition, and Metabolism.* 2012;37(4):803-806.

13. Canadian Fitness & Lifestyle Research Institute. *Physical Activity Levels of Canadians - 2008 Physical Activity Monitor*. 2010; http://cflri.ca/. Accessed July 17, 2013.

14. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports,*. 2011;22(1):7-14.

15. Kohl HW, 3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, Kahlmeier S. Physical Activity 5: The pandemic of physical inactivity: Global action for public health. *The Lancet.* 2012;380(9838):294-305.

16. Statistics Canada. *Population projections for Canada, provinces and territories.* Demography Division, ed. Ottawa, ON: Ministry of Industry, Government of Canada; 2010.

17. Gilmour H, Park J. Dependancy, chronic conditions and pain in seniors. *Health Reports.* 2006;16(Suppl):21-31.

18. Ramage-Morin PL, Shields M, Martel L. Health-promoting factors and good health among Canadians in mid- to late life. *Health Reports.* 2010;21(3):45-53.

19. Organization for Economic Co-operation and Development. *Health at a Glance 2011: OECD Indicators.* Paris, France: OECD Publishing;2011.

20. Vegda K, Nie J, Wang L, Tracy CS, Moineddin R, Upshur R. Trends in health services utilization, medication use, and health conditions among older adults: A 2-year retrospective chart review in a primary care practice. *BMC Health Services Research.* 2009;9(1):217.

21. Moineddin R, Nie J, Wang L, Tracy CS, Upshur R. Measuring change in health status of older adults at the population level: The transition probability model. *BMC Health Services Research.* 2010;10(1):306.

22. Craig CL. Evolution and devolution of national physical activity policy in Canada. *Journal of Physical Activity and Health.* 2011;8(1044-1056).

23. Lankenau B, Solari A, Pratt M. International physical activity policy development: A commentary. *Public Health Reports.* 2004;119(3):352-355.

24. Herman KM, Ardern CI, Mason C, Brien SE, Katzmarzyk PT. Trends in physical activity research in Canada. *Applied Physiology, Nutrition, and Metabolism.* 2007;32(3):400-408.

25. Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

26. Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

27. Anderson LH, Martinson BC, Crain AL, Pronk NP, Whitebird RR, O'Connor PJ, Fine LJ. Health care charges associated with physical inactivity, overweight, and obesity. *Preventing Chronic Disease.* 2005;2(4):A09.

28. Ackermann RT, Cheadle A, Sandhu N, Madsen L, Wagner EH, LoGerfo JP. Community exercise program use and changes in healthcare costs for older adults. *American Journal of Preventive Medicine.* 2003;25(3):232-237.

29. Chen IJ, Chou CL, Yu S, Cheng SP. Health services utilization and cost utility analysis of a walking program for residential community elderly. *Nursing Economics.* 2008;26(4):263-269.

30. Haapanen-Niemi N, Miilunpalo S, Vuori I, Pasanen M, Oja P. The impact of smoking, alcohol consumption, and physical activity on use of hospital services. *American Journal of Public Health.* 1999;89(5):691-698.

31. Keeler EB, Manning WG, Newhouse JP, Sloss EM, Wasserman J. The external costs of a sedentary lifestyle. *American Journal of Public Health.* 1989;79(8):975-981.

32. Manning WG, Keeler EB, Newhouse JP, Sloss EM, Wasserman J. *The Costs of Poor Health Habits.* Cambridge, MA: Harvard University Press; 1991.

33. Perkins AJ, Clark DO. Assessing the association of walking with health services use and costs among socioeconomically disadvantaged older adults. *Preventive Medicine.* 2001;32(6):492.

34. Sari N. A short walk a day shortens the hospital stay: Physical activity and the demand for hospital services for older adults. *Canadian Journal of Public Health.* 2010;101(5):385-389.

35. Andreyeva T, Sturm R. Physical activity and changes in health care costs in late middle age. *Journal of Physical Activity and Health.* 2006;3:S6-S19.

36. Petrella RJ, Pedersen L, Cunningham DA, Koval JJ, Paterson DH. Physician contact with older community patients: Is there an association with physical fitness? *Preventive Medicine.* 1999;29(6):571.

37. Borzecki AM, Lee A, Kalman D, Kazis LE. Do poor health behaviors affect health-related quality of life and healthcare utilization among veterans? *Journal of Ambulatory Care Management.* 2005;28(2):141-156.

38. Nguyen HQ, Ackermann RT, Maciejewski M, Berke EM, Patrick M, Williams B, LoGerfo JP. Managed-Medicare health club benefit and reduced health care costs among older adults. *Preventing Chronic Disease.* 2008;5(1):1-10.

39. Davis JC, Marra CA, Robertson MC, Najafzadeh MA, Liu-Ambrose T. Sustained economic benefit of resistance training in community-dwelling senior women. *Journal of the American Geriatrics Society.* 2011;59:1232-1237.

40. Dunlop S, Coyte PC, McIsaac W. Socio-economic status and the utilization of physicians' services: Results from the Canadian National Population Health Survey. *Social Science & Medicine.* 2000;51(2000):123-133.

41. Liu-Ambrose TY, Ashe MC, Marra C, Physical Activity and Chronic Conditions Research Team. Independent and inverse association of healthcare utilisation with

physical activity in older adults with multiple chronic conditions. *British Journal of Sports Medicine.* 2010;44(14):1024-1028.

42. Woolcott JC, Ashe MC, Millar WC, Shi P, Marra CA, PACC Research Team. Does physical activity reduce seniors' need for healthcare? A study of 24 281 Canadians. *British Journal of Sports Medicine.* 2010;44:902-904.

43. Plotnikoff RC, Karunamuni ND, Johnson JA, Kotovych M, Svenson LW. Health-related behaviours in adults with diabetes: Associations with health care utilization and costs. *Canadian Journal Of Public Health.* 2008;99(3):227-231.

44. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4):392-410.

45. Beland Y. Canadian Community Health Survey - Methodological overview. *Health Reports.* 2002;13(3):9-14.

46. Statistics Canada. *Canadian Community Health Survey Cycle 3.1 Master Microdata File User Guide*. Ottawa, ON: Statistics Canada; 2006.

47. Statistics Canada. *Response Rates by Province/Territory and Health Region. CCHS Cycle 3.1*. Ottawa, ON: Statistics Canada; 2006.

48. Asada Y, Kephart G. Equity in health services use and intensity of use in Canada. *BMC Health Services Research.* 2007;7(1):41.

49. Statistics Canada. *Canadian Community Health Survey Cycle 3.1 Final Questionnaire.* Ottawa, ON: Statistics Canada; 2005.

50. McColl M, Shortt S. Another way to look at high service utilization: The contribution of disability. *Journal of Health Services Research & Policy.* 2006;11(2):74-80.

51. Health Canada, Canadian Society for Exercise Physiology. *Canada's Physical Activity Guide for Older Adults*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1999.

52. Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the United States. *The Milbank Memorial Fund Quarterly.* 1973;51(1):95.

53. Andersen RM. Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior.* 1995;36(1):1-10.

54. Phillips KA, Morrison KR, Andersen R, LA A. Understanding the context of healthcare utilization: Assessing environmental and provider-related variables in the Behavioral Model of Utilization. *Health Services Research.* 1998;33(3):571-596.

55. Chad KE, Reeder BA, Harrison EL, et al. Profile of physical activity levels in community-dwelling older adults. *Medicine & Science in Sports & Exercise.* 2005;37(10):1774-1784.

56. Hilbe JM. *Negative Binomial Regression.* Cambridge: Cambridge University Press; 2007.

57. Lohr SL. *Sampling: Design and Analysis.* 2nd Edition. Boston, MA: Cengage Learning, Inc.; 2010.

58. Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obesity Research.* 2005;13(8):1450-1457.

59. Mitchell TL, Gobbons LW, Devers SM, Earnest CP. Effects of cardiorespiratory fitness on healthcare utilization. *Medicine & Science in Sports & Exercise.* 2004;36(12):2088-2092.

60. Costello E, Kafchinski M, Vrazel J, Sullivan P. Motivators, barriers, and beliefs regarding physical activity in an older adult population. *Journal of Geriatric Physical Therapy.* 2011;34(3):138-147.

61. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism.* 2010;35(6):725-740.

62. Washburn RA. Assessment of physical activity in older adults. *Research Quarterly for Exercise and Sport.* 2000;71:S79-S88.

63. Murphy SL. Review of physical activity measurement using accelerometers in older adults: Considerations for research design and conduct. *Preventive Medicine.* 2009;48(2):108-114.

64. Raina PS, Kirkland SA, Wolfson C, et al. Accessing health care utilization databases for health research: A Canadian Longitudinal Study on Aging feasibility study. *Canadian Journal on Aging.* 2009;28(Special Issue 03):287-294.

65. Roos LL, Brownell M, Lix L, Roos NP, Walld R, MacWilliam L. From health to research: Privacy, methods, approaches. *Social Science & Medicine.* 2008;66:117-129.

66. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine.* 2003;37(3):197-206.

CHAPTER FIVE

STUDY TWO

THE EFFECTS OF A RANDOMIZED, COMMUNITY-BASED PHYSICAL ACTIVITY INTERVENTION ON HEALTH SERVICES UTILIZATION IN COMMUNITY-DWELLING OLDER ADULTS

5.1 INTRODUCTION

By 2036, the number of seniors in Canada is projected to more than double, accounting for approximately one quarter of the total population.[1] This unprecedented growth of the older adult population is expected to have significant economic and societal implications both globally and for Canada.[2,3] Aging is associated with an increased incidence and prevalence of most chronic conditions along with increased impairment and disability associated with functional decline. Recent estimates suggest that by age 65, 77% of men and 85% of women will have at least one chronic condition, the most prevalent being cardiovascular disease, cancer, respiratory disease, arthritis and diabetes, and 25% will have four chronic conditions or more.[4,5] Consequently, there is growing concern about the potential pressures that an aging population will place on the health care system as a result of the increasing need and demand for long term management of chronic health conditions.[2,6,7]

Over the past decade, there has been increased interest in the potential role of physical activity as a strategy to reduce health services utilization and in turn, contain healthcare costs.[8-14] Low levels of physical activity are associated with a myriad of chronic conditions, including hypertension, overweight/obesity, dyslipidemia, coronary heart disease, type 2 diabetes mellitus, stroke, and depression.[15-19] The prevalence of these chronic conditions increases with age, as does their burden of illness and disability, therefore increasing PA among older adults may be an effective strategy to contain costs associated health services utilization in this population. However, studies examining relationships between physical activity and health services utilization among older adults are very limited, especially those considering the Canadian context.[13,20] There are very few prospective and/or longitudinal studies exploring the impact of PA and/or exercise interventions on health services utilization and costs in older adults. A recent systematic review of the literature identified fewer than 10 PA or exercise intervention studies that examined health services utilization or costs as an outcome, with fewer than five based on Canadian data.[13,21-23]

Buchner et al (1997) compared outpatient visits and the use of hospital services in a single-blinded randomized control trial examining the effect of strength and endurance training on gait, balance fall risk and health services use in community-living older adults.[24] Participants were randomized to one of three supervised training groups (aerobic training, strength training, or both) or to a non-exercise control group. The intervention consisted of supervised exercise (1-h sessions, three per week, for 24-26 weeks), followed by self-supervised exercise. Health service use was compared between the exercise and control groups for the 12-months pre- and post-intervention. Outpatient visits remained stable over time in the exercise groups but increased in the control group. However, there were no differences between the groups in outpatient costs. Hospital use following the intervention was similar between exercise and control groups, however control participants were more likely to spend more than 3 days in hospital ($p<.05$) and were more likely to accrue more than $5000 in hospital costs.[24]

Older adults have significantly higher rates of hospital admission than the general population, with persons aged 65 and older accounting for 40% of acute hospital stays in Canada.[2] Many older adults will experience some level of functional decline or deconditioning as a consequence of their hospitalization which may potentially affect their future independence and quality of life.[25] Therefore, the tertiary benefits of physical activity may be as significant as its role in primary prevention. Courtney et al (2009) examined the effect of an exercise-based model of post-hospitalization follow-up care in a group of older adults at risk for hospital readmission.[25] In their study, a 6-month home-based exercise program with nurse-provided in-person and telephone support resulted in 20% fewer emergency hospital readmissions and a 40% reduction in emergency use of local GP services in the intervention group compared to the usual care control group, noting also that the intervention group also exhibited significantly better health-related quality of life than the control group.[25]

In a retrospective cohort study Ackermann et al (2008) compared changes in healthcare costs between health maintenance organization (HMO) enrollees who participated in a physical activity benefit with a group of age and sex matched controls.[26] The program was a supervised, group-based exercise program designed to increase health and functional ability in sedentary, community-dwelling older adults. The supervised and instructor-led classes were offered three times per week at multiple community-based sites. In the first year of the program, healthcare costs were similar between the participant and control groups but by the second year, adjusted total costs were significantly lower among program participants compared to controls. In the 12-months after first attending the program, participants had a lower hospitalization rate but more primary care visits and higher primary care costs than controls; total and specialty care costs in this period were not significantly different between groups. During the second year (13–24 months after first attending), program participants still had higher primary care costs than controls, but they had significantly lower inpatient and total healthcare costs.[26] In a follow-up study examining a separate program for diabetic seniors, Nguyen et al (2008) found that the healthcare costs of frequent program users were 41% lower than infrequent users or non-participants.[27]

Chen et al (2008) used a prospective controlled trial to evaluate the effects of a 12-week walking program on health service utilization in community-dwelling older adults in Taiwan.[28] The 12-week walking intervention included three hospital-based, nurse-led walking sessions per week. After a 10 to 15 minute warm-up, participants were asked to walk for 20 to 30 minutes on a treadmill at a rating of perceived exertion (RPE) of 10 to 12 which was followed by a 10-minute cool-down period. Self-reported health service utilization measures included the number of hospitalizations, outpatient department or clinic visits, and emergency visits in the preceding 3-months. There were no significant differences between the walking and control groups in pre- and post- intervention changes in outpatient visits; however, the number of outpatient visits increased significantly in the control group while in the walking group, there was no significant change in outpatient visits. Furthermore, there were significantly fewer hospital admissions in the walking group after the 12-week intervention compared to the control group, in which there were no hospital admissions either pre- or post-intervention.[28]

To date, the only published Canadian data examining the effect of a PA or exercise intervention on subsequent health services utilization have been a series of economic evaluations of exercise interventions aimed at falls prevention and executive cognitive function published by Davis and colleagues.[21-23] The first study determined the cost-effectiveness and cost-utility ratio of a 12-month randomized control trial (RCT) of resistance training in 155 women aged 65 to 75 years.[23] Participants were randomized to one of three groups: once-weekly or twice-weekly high intensity resistance training intervention or a twice-weekly balance and toning control group. In this study, mean total healthcare costs, based on visits to health care professionals, hospital visits and admissions, and laboratory and diagnostic testing, were found to be lower among participants in the two resistance training intervention groups compared to the wellness-based, balance and toning control group.[23] A follow-up study examining the sustained effects of this intervention subsequently reported that the mean total healthcare costs remained lower in the intervention groups compared to the control group in the 12 months following the cessation of the intervention even though the health benefits obtained in the trial were not sustained.[21]

In 2013, Davis et al published a similar study of a 6-month RCT of resistance and aerobic training for community-dwelling women reporting mild cognitive impairments.[22] In this study, participants were randomized to a twice-weekly, class-based resistance training program, a twice-weekly, class-based aerobic training (outdoor walking) program or a twice-weekly balance and toning control group. Mean total healthcare costs over the 6-months were lower in both the resistance training and the aerobic training groups compared to a balance and toning exercise control group; however, mean costs for health professional visits and hospital admissions were higher in the resistance training group compared to the aerobic training group.[22]

The small group of intervention studies outlined above provide general support for the potential of PA as a potential target for strategies aimed at reducing health care utilization and containment of health care costs; however, wide variations in study methodologies and the overall scarcity of Canadian data make firm generalizations problematic.[13] Furthermore, the relatively short follow-up periods (3- to 21-months considered) leave open the question of the longer-term effects of PA and exercise on health services utilization. Prospective longitudinal studies with longer follow-up periods are needed in order to gain better understand the complex relationships between PA and health services utilization in older adults, particularly in the Canadian context.

In 2000, the Saskatoon Health Region partnered with the University of Saskatchewan, the City of Saskatoon and ParticipACTION to develop and implement a community-based PA health promotion strategy. Separate community strategies, with a parallel research program, were developed for six targeted populations, one of which was older adults. As part of the older adult strategy, a randomized clinical trial (RCT) (50+ *in motion*) was undertaken to compare the effectiveness of a class-based (CB) and home-based (HB) exercise program for older adults with chronic health conditions, with the overall aim being to better understand the impact of community-based PA programs on health status and health care utilization and costs in this population.[29] The objective of this study was to examine the long-term effects of the 50+ *in motion* trial on health service utilization (HSU) and health care costs (HCC) in adults aged 50 years and older. While it was thought that the 50+ *in motion* participants assigned to the CB group may derive more benefit from a closely monitored environment, a lack of consensus in the literature as to the superiority of CB exercise programs in the older adult population precluded the formation of a specific hypothesis for this question. Changes in HSU and HCC as a function of PA level, cardiorespiratory endurance, and physical function were also examined. It was hypothesized that HSU and HCC would be lower among participants who were more physically active, had better cardiorespiratory endurance and physical function, and maintained their activity level, fitness, and functional ability over the 5 year study period.

5.2 METHODS

The methods for this study are presented in four parts. The first part provides a brief description of the 50+ *in motion* RCT, including its study population and methodology while in the second section, a summary of the methods pertaining to the access and use of the health services utilization and cost data is presented. Following this, a description of the study variables is provided along with the statistical methods.

Approval for this study was obtained from the University of Saskatchewan Advisory Committee on Ethics in Biomedical Research and the Saskatchewan Health Data Access Review Committee (Appendix A-1), and informed written consent was obtained from all participants (Appendix A-1). Additional consent was sought from participants in order to access individual health services utilization data through the Saskatchewan Health database.

5.2.1 50+ in motion Randomized Clinical Trial

The 50+ *in motion* intervention was a randomized clinical trial that ran from September 2002 until August 2004, with annual follow-up continuing until August 2007. The purpose of the intervention was to compare the effectiveness of a class-based (CB) and home-based (HB) exercise program for older adults with stable chronic health conditions including hypertension, dyslipidemia, type 2 diabetes mellitus, osteoarthritis, overweight or obesity. Given that regular physical activity is recommended as the standard of care for the above conditions, a non-exercising or wait-list control group was not included for ethical reasons. The primary outcomes of interest were physical fitness, function and health status, along with health services utilization and health care costs. The detailed methodology of this trial specific to participant recruitment, randomization, and intervention design is described in full in Lindstrom et al (2004) and Reeder et al (2008).[29,30]

Participants

A total of 172 sedentary older adults were enrolled in the intervention and were assigned using a randomized block design to either a CB or HB exercise intervention. Participants recruited were over the age of 50 years (mean = 60.3 years, *SD* = 7.42), sedentary, were free of cardiovascular and respiratory disease but were diagnosed with one or more of the following chronic health conditions: type 2 diabetes mellitus, hypertension, dyslipidemia, osteoarthritis, or overweight (BMI ≥ 25) or obesity (BMI ≥ 30). All participants received medical clearance to participate in an exercise program of moderate intensity.[29,30]

Intervention

The initial intervention consisted of a 3-month, intensive phase and a 9-month follow-up period. For those assigned to the CB program, the intensive phase involved 60 minutes of structured, instructor-led, exercise in a community recreation facility 3 times a week. Sessions included stretching, endurance and weight training exercises and a series of weekly lifestyle education classes. Participation in these sessions was at a monthly cost per participant of either $20 Canadian (for diabetics) or $35 Canadian (all other participants). At the conclusion of the 3-month intensive phase, participants were provided with written information on the physical activity opportunities within their community and encouraged to remain active throughout the 9-month follow-up period.

During the intensive phase of the HB program, participants initially met with an exercise therapist who helped to design an individualized physical activity program for them to follow on their own at home or in the community. All individual activity programs were based on Canada's 1998 physical activity guidelines for older adults, were comparable in frequency, intensity and duration to the class-based program and included stretching exercises, moderately vigorous endurance exercise, and light resistance training.[31] In accordance with recommendations outlined by King et al (1998), the HB group were provided with support through follow-up telephone contacts that decreased in frequency (from weekly to monthly) through the 12-month study period. Participants in the HB group were also offered identical, but separate, lifestyle education classes as those provided in the CB program. These sessions were offered in two community facilities in different areas of the city multiple times during the year to accommodate the rolling enrolment period.[29,32]

Participants were assessed prior to randomization (baseline), at the end of the intensive phase (3 months), 3-months into the follow-up period (6 months) and immediately following the 9-month follow-up period (Yr. 1). After 12-months, participants continued to be followed annually for three additional years (Yrs. 2-4). The immediate (baseline – 3-months) and short-term health (baseline – Yr.1) outcomes of the intervention have been reported elsewhere.[29,33]

Procedures

At each time point, participants completed a series of questionnaires that included standard socio-demographic items and a battery of previously validated instruments measuring health status and self-reported physical activity.[34-42] Participants also underwent a physical assessment that included standard measurements of blood pressure, height, weight, waist circumference, along with assessments of physical fitness and functional ability. All testing was carried out by trained personnel, all of whom were blind to the participants' group allocation. All study personnel were Certified Exercise Physiologists (CEPs) as designated by the Canadian Society for Exercise Physiology (CSEP).

5.2.2 Health Services Utilization and Cost Data

A proposal requesting access to participants' Saskatchewan Health utilization data was submitted to Saskatchewan Health in March 2003 and approved in September 2003 (Appendix A-1/A-2). The health services numbers and dates of birth of consenting participants were provided to Saskatchewan Health, along with a researcher assigned identifier for the purposes of data abstraction. Five years of health service utilization data including physician services, hospitalizations, and prescription drug records were requested, beginning the year prior to enrolment in the 50+ *in motion* study and continuing through the intervention year and for three years following the intervention period.

As detailed in Chapter 3, the requested data was housed on three separate administrative databases which, once released by the Ministry, were linked along with the physical data from the 50+ *in motion* study using the researcher assigned identifier. Demographic data obtained through the Population Registry included an indicator of registered Indian status, dates of coverage initiation and termination, reason for coverage termination (death, emigration or study termination date) and an indicator for death. Data pertaining physician services was obtained through the Medical Services File and included information related to medical practitioner specialty (family practice, specialist or other) as well as service and diagnostic information including the date of service, diagnosis, and the approved amount paid for the service. Information about all acute care in-patient hospital separations and day surgeries was provided in the Hospital Services File. This data obtained included admission date, discharge date, type of admission (day surgery; inpatient), diagnosis(es), diagnosis type (most responsible; pre-admission co-morbidity; post-admission co-morbidity; secondary; external cause of injury), procedure(s) performed, date of procedure, and intensity weight. The cost of a given hospitalization can be calculated by multiplying the assigned weight by the estimated funding per weighted case for a given fiscal year.[43]

5.2.3 Study Variables

A brief summary of all study variables as they were included in the analyses is presented below. A timeline outlining the study data collection is provided in Figure 5.1. The dependent variables were derived from Saskatchewan Health administrative data while the independent variables were obtained from data collected in the 50+ *in motion* clinical trial.

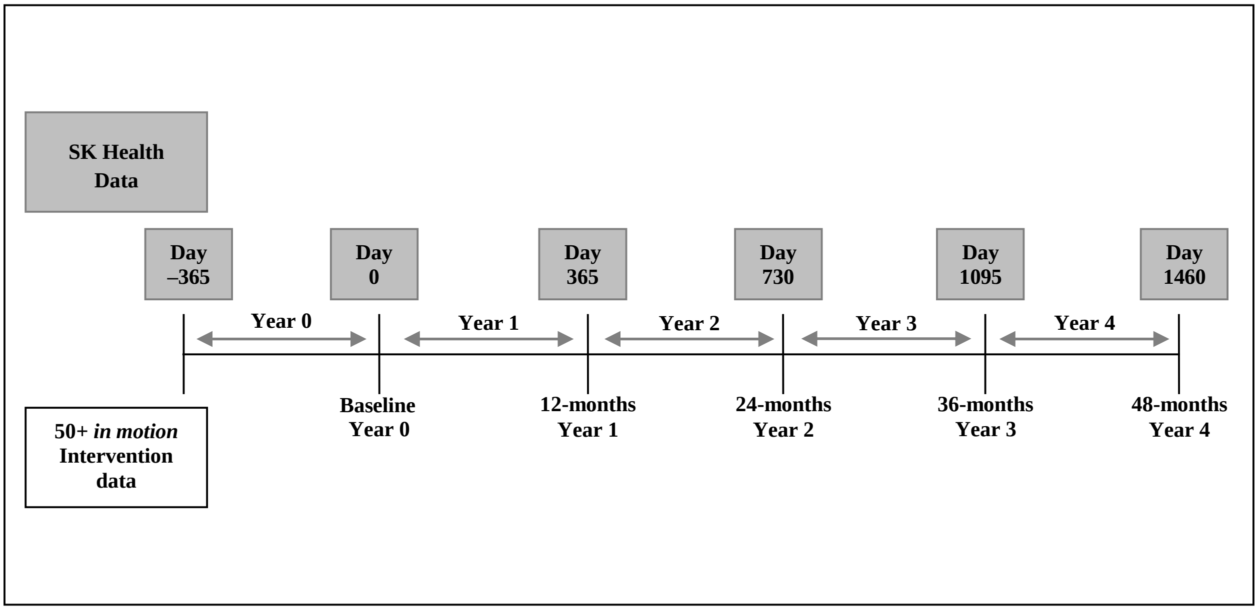


Figure 5.1 Timeline for 50+ *in motion* RCT

5.2.3.1 Dependent Variables

In this study, there were two primary outcomes of interest: (1) health services utilization and (2) costs associated with health services utilization.

Health Services Utilization

In the present study health services utilization is operationalized as the use of general physician (GP) services, specialist physician services, and hospital services. For each category of utilization, two or more variables were constructed in order to examine both contacts (use versus non-use) and/or intensity (volume or frequency) of utilization. For each health record, the service year was determined by subtracting the index data (date of study entry) from the service date. If the difference was negative, the service occurred prior to the participant's entry into the study and therefore, was designated as occurring in the baseline year (Yr. 0). Differences between 1 and 365 were designated as occurring in Yr. 1; between 366 and 730 were Yr. 2; between 731 and 1095 were Yr3; between 1096 and 1460 were Yr. 4.

General physician services

Two variables were constructed to assess use of GP physician services: a count variable indicating the number of GP visits per year and a dichotomous variable indicating high use of GP services. Given there is little consensus on what constitutes high use of physician services in the literature, the cut point for high use was set at the mean ± 1SD, based on baseline utilization data.[44,45]

Specialist physician services

Three variables were constructed to assess the use of specialist physician services: a dichotomous variable indicating contact with a specialist physician in a given year (yes/no), a count variable indicating the number of specialist visits in a given year and a dichotomous variable indicating high use of specialist physician services. The cut point for high use of specialist services was set at the mean ± 1SD, based on baseline utilization data.

Hospital services

Several variables were constructed to describe the use of hospital services: a dichotomous variable indicating whether or not the participant had been admitted to hospital in a given year (yes/no), a dichotomous variable indicating the type of hospital stay (day surgery/inpatient), and a count variable indicating the total number of hospital nights spent in hospital in a given year.

<u>*Health Services Costs*</u>

In order account for inflation and facilitate comparisons of costs across multiple years, the yearly costs were adjusted to 2008 dollars using the Consumer Price Index.[46]

Physician Costs – Family physician and Specialist physician

Annual costs for both GP and specialist physician services were calculated for each participant by summing the approved amounts paid listed in all single visit records in a given time period.[43]

Hospital Costs

The cost per hospitalization or day surgery was estimated by multiplying the resource intensity weight (RIW) or day procedure group (DPG) weight by the estimated funding per weighted case for the fiscal year in which the hospitalization occurred, as provided by the Saskatchewan Ministry of Health. Based on funding provided by Saskatchewan Health for acute care, the fiscal year estimated funding per weighted case is derived from analyses of historical staffing and other cost standards.[43] Total hospital costs were determined for each participant by summing all day surgery and inpatient costs incurred in each study year.

5.2.3.2 Independent Variables

The independent variables were all drawn from data collected from participants at baseline and at 4 follow-up time points (Yrs. 1-4) in the 50+ *in motion* clinical trial. The selection of independent variables was guided by the Andersen-Newman Behavioral Model of Health Services Utilization (BMHSU), which posits that the decision to seek medical care is influenced by several individual predisposing, enabling and health need determinants, personal health practices, and factors associated with the health care system and the external environment.[47,48] In this study, only the individual level determinants and personal health practices were considered in the analysis.

Predisposing Factors

Predisposing factors refer to the socio-cultural characteristics that influence an individual's propensity to use health services before they have a need to do so. These include demographic characteristics (age, gender), social structure (marital status, education, ethnicity), and health-related beliefs (factors related to a person's knowledge, attitudes and values related to health, illness and health services). The following predisposing factors were considered in the initial analyses: age, sex, marital status (7 levels - married; common-law; living with a partner; separated; divorced; widowed; never married) and education. Education was measured as an 8 level categorical variable (no formal schooling; elementary school only; some secondary; secondary/high school graduation; some post-secondary; post-secondary diploma or certificate; university degree; degree in medicine, dentistry, veterinary medicine, optometry or post-graduate degree – Master's or Doctorate).

Enabling Factors

Enabling factors are those conditions that facilitate or impede one's ability to obtain health care services. Employment status and annual household income were included as enabling factors in the initial analyses. Employment status was a categorical variable with 4 levels: full-time; part-time; retired; unemployed, while annual household income (in Canadian dollars) was assessed using a 6 level categorical variable (< $20,000; $20,000-$30,000; $30,000-$40,000; $40,000-$50,000; $50,000-$60,000; >$60,000).

Health Need

Need factors include one's perceived and evaluated health, illness, and functional status. The following variables were considered in the initial analyses as factors indicative of the need for health services.

Health Status

The Medical Outcomes Short Form – 12 (SF-12v.2) was used to assess health status and health-related quality of life.[35] Two summary scores – the Physical Component Summary scale (PCS-12) and the Mental Component Summary scale (MCS-12) are derived from responses to 12 Likert scale and dichotomous (yes/no) questions, resulting in scores on a scale of 0 to 100. Scores from this widely used instrument are highly correlated with the longer SF-36 instrument and have been shown to provide valid comparisons between groups to detect changes associated with physical and mental health.[35] The minimum difference in scores thought to be clinically meaningful is suggested to be approximately 5 points.[54]

Co-morbid Conditions

Participants were asked to identify from a listing any medically diagnosed conditions that have affected their overall health for longer than six months. These conditions included: musculoskeletal problems, breathing problems, heart and circulation problems, digestive system problems, kidney, bladder or urinary problems, neurological problems, mental or emotional problems, cancer, blood problems, eye problems, high blood pressure, diabetes and others, unspecified above. The descriptions for questions related to defining chronic health conditions were based on items from the National Population Health Survey.[42] For analytical purposes, an indicator of comorbidity was calculated as the total number of conditions reported.[55]

Blood Pressure

Systolic and diastolic blood pressure readings were used to estimate MAP according the following formula: MAP = DBP + [1/3 (SBP – DBP)].[29] Mean arterial pressure (MAP) is a measure of the average pressure exerted against arterial walls during the entire cardiac cycle.[53]

Body Composition

Overweight and obesity were assessed using body mass index (BMI), calculated as weight (kg) divided by height (m^2), and waist circumference (WC), both of which were included in the analysis.[29]

Cardiovascular endurance

Cardiovascular endurance was assessed using the 6 Minute Walk test (6MWT).[49] Participants were instructed to walk as far as they could in six minutes. Testers informed participants of the time elapsed after two and four minutes. Scores were determined as the total distance covered (meters) in six minutes.

Functional fitness and performance

Functional fitness was assessed using selected tests from the Functional Fitness Test.[50] The specific measures included in the present study included a chair stand test as a measure of lower body strength and endurance (Sit to Stand Test) and an arm curl task as a measure of upper body strength and endurance (arm curls).[50] The Physical Performance Test (PPT) was used to assess participants' ability to perform activities of daily living (ADLs) relevant to the older adult.[51] This 9-item test battery includes assessments of ADLs that capture aerobic function, flexibility and balance. Example tasks include climbing stairs, picking an article off the floor, turning 360 degrees and putting on a jacket. Scores are calculated based on a point system and item scores are then summed to provide a total score out of a possible 36 points, with higher scores reflective of better physical performance.[51] Stair climbing, in particular, has been identified as a marker of functional independence in older adults and it is among the most common tasks that community dwelling older adults report as most difficult due to 'old age'.[52] Therefore, the timed stair climbing task was also included as a separate variable in the initial analyses.

Personal Health Practices

The primary personal health practices of interest were physical activity and sedentary behaviour. A categorical variable describing participants smoking status (3 level – non-smoker; former smoker; current smoker) was also included in the analysis.

Physical Activity and Sedentary Behaviour

The Physical Activity Scale for the Elderly (PASE) was used to assess participants' recent participation in physical activity.[37] The 12-item questionnaire measures participation in sedentary, leisure, household and occupational activities over the previous 7 days and has been validated for use in both healthy and clinical populations.[36,38,40,41] Scores on the PASE for each of the 12 activities were computed by multiplying duration of activity (hours/week) or participation in an activity (yes/no) by empirically derived weights. These weights were based on Caltrac counts, daily energy expenditures (metabolic equivalents; METs) and self-reported physical activity. The total PASE score was calculated as the sum of the products of all 12 items, with a higher score indicative of greater levels of PA.[37] Sedentary activities are scored as 'zero' in computing the PASE score, so this item was used to derive a separate variable indicating the duration of time spent in sedentary pursuits in hours/week.

5.2.4 Statistical Methods

All analyses were completed using the SPSS Statistics 20 (IBM, 2012). Level of significance was defined as p <0.05, except where otherwise noted. Baseline characteristics were compared between participants who granted access to their administrative data and those who refused using chi square and ANOVA for categorical and continuous variables, respectively.

Baseline characteristics for the study population were described overall and by randomization group using frequencies or means ± SD as appropriate for all variables of interest.

When sample sizes within levels of categorical independent variables were small, the variable categories were collapsed. Marital status was collapsed from seven categories into two categories: married (married/common law/living with a partner) and not married (separated/divorced/widowed/never married). Education was recoded into a dichotomous variable indicating whether or not participants had any post-secondary education. Employment status was collapsed into a dichotomous variable indicating if the participant was retired (yes/no). Income was dichotomized from its original six levels to two levels (≤$30,000; >$30,000 per year). Smoking status was recoded from a three level variable (smoker, former smoker or non-smoker) into a dichotomous variable indicating if the participant was a non-smoker or a current/former smoker.

The longitudinal changes in intervention outcomes were compared between the CB and HB groups using the Generalized Estimating Equations (GEE) approach.[56] This approach permits the specification of a within-subject covariance structure in order to account for interdependence due to repeated measurements. Separate linear and Poisson models were used to analyze continuous and count intervention outcomes, respectively. Each model used an exchangeable covariance structure with time as the repeated factor, and randomization group (CB/HB) and the group x time interaction were included as fixed factors. The exchangeable within-subject covariance structure, which assumes that correlations between subsequent measurements are the same, was selected based on the correlation structure of the observed data.[57] Contrast analyses with a Bonferroni correction were conducted to analyze within-group changes in each outcome measure.

In order to assess the longitudinal effects of randomization group on health services utilization and health care costs, a similar approach was used. Separate longitudinal GEE models were developed for each dependent variable. A negative binomial distribution was used to model count-based health services utilization variables, while normal and binary logistic distributions were used to model continuous and dichotomous dependent variables, respectively. Contrast analyses with a Bonferroni correction were conducted to analyze within-group changes in each outcome measure. Each model used an exchangeable covariance structure with time as the repeated factor, and randomization group (CB/HB) and the group x time interaction were included as fixed factors. As detailed in Chapter 3, covariates were selected for inclusion in the longitudinal models through methods of purposeful selection based on clinical importance, statistical significance and the effect that removal of the variable had on the beta coefficient of the remaining variables.[58] Independent variables found to be significantly related (p<0.25) to the dependent variable were included in the initial model, along with the fixed factors and variables that were deemed to be important from a theoretical or clinical perspective.[58] Variables were added to the initial model in a single block and those that were not significantly associated with the model were then removed. In the variables related to specialist physician services, the number of GP visits was retained as a potential confounder because, to a certain degree, access to specialists is controlled by GP physicians. Likewise, annual visits to GP and specialist physicians were retained as possible confounders in the models related to hospital services. Confounding related to other variables was assessed by re-introducing the excluded variables back into the model one by one. When the re-introduction of a variable produced a meaningful difference in estimates (≥ 20% change), the variable in question was retained in the model as a confounder.[58]

The GEE approach outlined above assumes that missing data are missing completely at random.[56] However, preliminary analyses revealed systematic differences (p<.10) between those participants with complete data and those with missing data at one or more time points on several independent variables. In order to account for this, the pattern of missing data was incorporated into the initial models. This was done through the inclusion of a categorical 'drop' variable. The 'drop' variable had six categories defined as: 1= participation at every time point (baseline, Yr. 1, Yr. 2, Yr. 3 and Yr. 4); 2=participation at 4 consecutive time points (baseline, Yr. 1, Yr. 2 and Yr. 3); 3=participation at 3 consecutive time points (baseline, Yr. 1 and Yr. 2); 4= participation at 2 consecutive time points (baseline and Yr. 1), 5= participation at baseline only, and 6=intermittent participation. Statistical models which incorporate the pattern of missing data are called pattern-mixture models. In longitudinal studies, it is believed that this approach allows for a more appropriate handling of missing data than does the imputation of the intention-to-treat approach.[59-61] In instances where the initial statistical models failed to converge, a simplified drop variable was substituted for the original drop variable. To derive this variable, the original drop variable was recoded from its original six levels to a 4-level variable (participation at every time point; participation at 4 time points, participation at 3 time points, participation at two or fewer time points).

5.3 RESULTS

Figure 5.2 illustrates the flow of participants through the 50+ *in motion* intervention. Of the 172 participants initially enrolled in the 50+ *in motion* study, 128 (74.4%) agreed to permit access to their administrative health data through Saskatchewan Health. The mean age of these participants was 60.7 ± 7.4 years and the majority were female (73%), had some post-secondary education (91%) and reported being overweight or obese (93%).

A comparison of select baseline characteristics between participants granting access to their SK health data and those who refused to consent is presented in Tables 5.1a and 5.1b. The two groups were not significantly different in terms of age, sex, education, ethnicity, or randomization group assignment. Similarly, the proportion of people with each specific chronic condition required for study inclusion did not differ between consenters and non-consenters. However, a significantly greater proportion of those allowing data access had been diagnosed with more than 1 of the required conditions. Approximately 84% of consenters had more than 1 condition of interest compared to 66% of non-consenters ($\chi^2 = 6.30$; $p<.05$). Lastly, the groups did not differ on the majority of physical measures with the exception of the SF-12 mental component score, where consenting participants had significantly better mental component scores than those who did not consent (51.5±8.6 vs. 47.0±10.4; $p<.05$).

Figure 5.2 Participant flow diagram for the 50+ *in motion* intervention

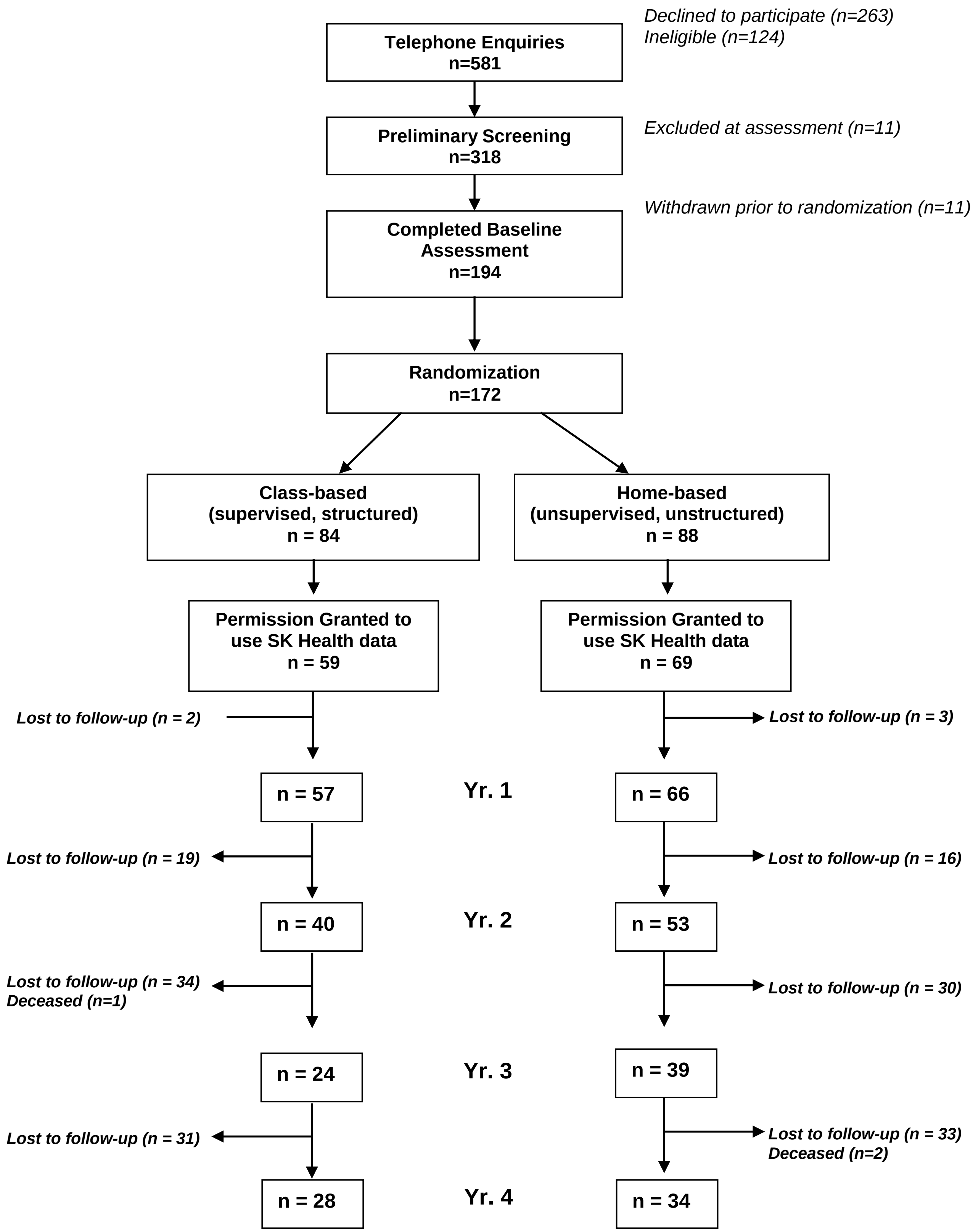


Table 5.1a Comparison of select baseline socio-demographic characteristics between participants who consented to and those who denied access to their administrative health data.

	Access to SK Health Data			Access to SK Health Data	
	Consented *n*=128	Refused *n*=44		Consented *n*=128	Refused *n*=44
Age (mean±SD)	60.7 ± 7.4	59.4 ± 7.5			
	n (%)	*n* (%)		n (%)	*n* (%)
Sex			*Randomization Group*		
Male	34 (26.6)	12 (27.3)	Class-based	59 (46.1)	25 (56.8)
Female	94 (73.4)	32 (72.7)	Home-based	69 (53.9)	19 (43.2)
Post-secondary education			*Condition of interest*		
Yes	112 (87.5)	40 (90.9)	Overweight/Obesity		
No	16 (12.5)	3 (6.8)	Yes	119 (93.0)	38 (86.4)
Missing	0 (0.0)	1 (2.3)	No	9 (7.0)	6 (13.6)
Income			Dyslipidemia		
≤ $30,000	28 (21.9)	10 (22.7)	Yes	59 (46.1)	18 (40.9)
> $30,000	93 (72.7)	30 (68.2)	No	69 (53.9)	26 (59.1)
Missing	7 (5.5)	4 (9.1)	Hypertension		
Employment status			Yes	55 (43.0)	16 (36.4)
Employed	61 (47.7)	25 (56.8)	No	73 (57.0)	28 (63.6)
Not employed	67 (52.3)	18 (40.9)	Osteoarthritis		
Missing	0 (0.0)	1 (2.3)	Yes	47 (36.7)	12 (27.3)
*Marital status**			No	81 (63.3)	32 (72.7)
Married	95 (74.2)	26 (59.1)	Diabetes		
Not married	32 (25.0)	18 (40.9)	Yes	12 (9.4)	3 (6.8)
Missing	1 (0.8)		No	116 (90.6)	41 (93.2)
Ethnicity			*Co-morbidity in conditions of interest**		
Aboriginal	0 (0.0)	1 (2.3)	1 condition	21 (16.4)	15 (34.1)
Non-Aboriginal	128 (100.0)	43 (97.7)	2 conditions	63 (49.2)	16 (36.4)
			3 or more conditions	44 (34.4)	13 (29.5)

*Significant difference between groups; $p<.05$

Table 5.1b Comparison of select baseline physical characteristics between participants who consented to and those who denied access to their administrative health data.

	Access to SK Health Data			
	Consented (n=128)		Refused (n=44)	
	n	*Mean ± SD*	*n*	*Mean ± SD*
Physical Activity				
PASE Score	126	130.8 ± 65.4	41	127.5 ± 62.1
Sedentary time (hr/week)	121	17.2 ± 8.76	40	19.6 ± 8.40
Blood Pressure				
Mean Arterial Pressure (mmHg)	128	96.3 ± 10.0	44	95.3 ± 10.6
Body Composition				
Body Mass Index ($kg \cdot m^{-2}$)	128	30.4 ± 4.3	44	30.6 ± 5.1
Waist Circumference (cm)	128	98.9 ± 13.4	44	99.7 ± 14.6
Cardiovascular Fitness				
6-Minute Walk Test (m)	127	554.5 ± 66.5	44	561.2 ± 59.4
Functional fitness & performance				
Chair Sit to Stand Test (# in 30s)	127	12.0 ± 3.0	44	11.8 ± 2.7
Arm Curl Test	128	14.3 ± 4.1	44	13.5 ± 2.7
Physical Performance Test (out of 36)	128	33.4 ± 2.4	44	33.7 ± 2.7
Timed Stair Climb Test (s)	125	4.5 ± 1.1	43	4.5 ± 1.0
Health Status				
SF-12 Physical	116	47.1 ± 8.6	36	46.2 ± 8.3
SF-12 Mental	116	51.5 ± 8.6*	36	47.0 ± 10.4

*Significant difference between groups; $p<.05$

The pattern of participation in the follow-up cycles of the 50+ *in motion* study was compared between those who consented to and those who denied access to their administrative health data (Table 5.2). Approximately 30% (38/128) of consenters had complete data across all time points compared to just 1 of the 44 (~2%) non-consenters. In fact, 33/44 (75%) of those who denied access to their SK Health data did not participate in any of the 4 follow-up data collection cycles. There were no baseline differences between consenters and non-consenters except on the measure for mental health status. Those who did not consent to the use of their administrative data had significantly lower SF-12 mental component scores compared to those who did consent (47.0 vs. 51.5; $p<.05$).

Table 5.2 Comparison of participation in 50+ *in motion* study between those granting and refusing access to SK Health data.

Time Point					Number of Participants		
					Access to SK Health Data		
Baseline	Yr. 1	Yr. 2	Yr. 3	Yr. 4	Yes	No	Total
√	√	√	√	√	38	1	39
√	√	√	√	–	18	3	21
√	√	√	–	–	17	2	19
√	√	–	–	–	25	3	28
√	–	–	–	–	1	33	34
Intermittent Missing[a]					29	2	31
TOTAL					128	44	172

[a] Intermittent missing category includes all other possible patterns of missing data

5.3.1 *Descriptive analysis*

The pattern of participation in the follow-up cycles of the 50+ *in motion* study was compared between CB and HB intervention groups (Table 5.3). Approximately 24% (14/59) of participants in the CB group had complete data across all time points while close to 35% (24/69) of those in the HB group completed measures at all four follow-up periods. Differences in the pattern of participation between the two groups were not statistically significant.

Table 5.3 Comparison of participation in 50+ *in motion* study between class-based (CB) and home-based (HB) intervention groups.

Time Point					Number of Participants		
Baseline	Yr. 1	Yr. 2	Yr. 3	Yr. 4	CB	HB	Total
√	√	√	√	√	14	24	38
√	√	√	√	–	7	11	18
√	√	√	–	–	9	8	17
√	√	–	–	–	13	12	25
√	–	–	–	–	0	1	1
Intermittent Missing[a]					16	13	29
TOTAL					59	69	128

[a] Intermittent missing category includes all other possible patterns of missing data

The baseline sociodemographic and health characteristics of the study population are presented in Tables 5.4a. The overall mean age of participants was 60.7±7.4 years. The majority were female (73.4%), of non-Aboriginal descent (100%) and had at least some post-secondary education (91.4%). The most prevalent of the chronic conditions required for study inclusion were overweight/obesity (93.0%), hypertension (43.0%) and abnormal cholesterol (46.1%) with a substantial proportion of participants (~84%) reporting multiple conditions of interest. When comparing baseline characteristics across randomization groups, analyses revealed no significant differences between the CB and HB groups.

Table 5.4a Baseline 50+ *in motion* socio-demographic characteristics – overall and stratified by randomization group.

	Randomization Group		
	Class-based *n*=59	Home-based *n*=69	Overall *N*=128
Age (mean±SD)	60.9 ± 7.1	60.4 ± 7.6	60.7 ± 7.4
	n (%)	*n* (%)	*n* (%)
Gender			
Male	16 (27.1)	18 (26.1)	34 (26.6)
Female	43 (72.9)	51 (73.9)	94 (73.4)
Post-Secondary Education			
Yes	50 (84.7)	62 (89.9)	112 (87.5)
No	9 (15.3)	7 (10.1)	16 (12.5)
Income			
≤ $30,000	14 (23.7)	14 (20.3)	28 (21.9)
> $30,000	42 (71.2)	51 (73.9)	93 (72.7)
Missing	3 (5.1)	4 (5.8)	7 (5.5)
Marital status			
Married	47 (79.7)	47 (79.7)	32 (74.2)
Not married	12 (20.3)	12 (20.3)	95 (25.0)
Missing	0 (0.0)	1 (1.4)	1 (0.8)
Employment status			
Employed	26 (44.1)	35 (50.7)	61 (47.7)
Not employed	33 (55.9)	34 (49.3)	67 (52.3)
Ethnicity			
Aboriginal	0 (0.0)	0 (0.0)	0 (0.0)
Non-Aboriginal	59 (100.0)	69 (100.0)	128 (100.0)
Hypertension			
Yes	25 (42.4)	30 (43.5)	55 (43.0)
No	34 (57.6)	39 (56.5)	73 (57.0)
Dyslipidemia			
Yes	26 (44.1)	33 (47.8)	59 (46.1)
No	33 (55.9)	36 (52.2)	69 (53.9)
Diabetes			
Yes	6 (10.2)	6 (8.7)	12 (9.4)
No	53 (89.8)	63 (91.3)	116 (90.6)
Osteoarthritis			
Yes	20 (33.9)	27 (39.1)	47 (36.7)
No	39 (66.1)	42 (60.9)	81 (63.3)
Overweight/Obesity			
Yes	54 (91.5)	65 (94.2)	119 (93.0)
No	5 (8.5)	4 (5.8)	9 (7.0)
Co-morbid Conditions			
1 condition	11 (18.6)	10 (14.5)	21 (16.4)
2 conditions	31 (52.5)	32 (46.4)	63 (49.2)
3 or more conditions	17 (28.8)	27 (39.1)	44 (34.4)

* Significant difference between groups; $p<.05$

The baseline fitness and health data of the study population are presented in Table 5.4b. There were no significant baseline differences between CB and HB groups on any fitness or health variables. Participants had an average PASE score of 130.8 and spent approximately 17 hours/week in sedentary pursuits such as reading and watching television. Overall, the mean BMI and waist circumference of participants was 30.4±4.3 kg/m^2 and 98.9 ± 13.4 cm, respectively. Participants walked, on average, approximately 550 meters in 6 minutes and climbed a single flight of stairs in approximately 4.5 seconds. Mean MCS-12 were slightly higher than the standardized mean of 50 while the PCS-12 were slightly lower than 50, reflecting better or worse than average function, respectively.

Adherence to the intervention

Information about the level of adherence by each intervention group for the 12-month intervention is provided in Table 5.5. At the end of the 3-month intensive intervention, approximately 80% of individuals in both groups reported some participation each week in endurance, strength and flexibility activities; this dropped to 65% by 12 months. The average volume of self-reported endurance activities decreased from 140 minutes/week at baseline to 122.6 minutes/week at 12 months in the CB group but increased from 169.5 to 185.9 minutes/week in the HB group (p<.05). The average volume of self-reported strength activities decreased at 6 months in both groups but returned to the 3-month level by the end of Yr. 1. The average volume of self-reported flexibility activities did not significantly change over the intervention year and was not significantly different between groups.[29,33]

Table 5.4b Baseline 50+ *in motion* fitness and health characteristics – overall and stratified by randomization group.

	Randomization Group				Overall	
	Class-based		Home-based			
	n	*Mean* ± *SD*	*n*	*Mean* ± *SD*	*n*	*Mean* ± *SD*
Physical Activity						
PASE Score (arbitrary units)	58	121.7 ± 58.2	68	138.5 ± 70.4	126	130.8 ± 65.4
Sedentary time (hrs/wk)	54	16.07 ± 8.55	67	18.12 ± 8.90	121	17.20 ± 8.76
Blood Pressure						
Mean Arterial Pressure (mmHg)	59	95.5 ± 10.1	69	97.0 ± 9.9	128	96.3 ± 10.0
Body Composition						
Body Mass Index ($kg \cdot m^{-2}$)	59	30.1 ± 4.4	69	30.6 ± 4.3	128	30.4 ± 4.3
Waist Circumference (cm)	59	98.4 ± 11.9	69	99.3 ± 14.5	128	98.9 ± 13.4
Cardiovascular Fitness						
6-Minute Walk Test (m)	58	546.0 ± 69.8	69	561.5 ± 63.3	127	554.5 ± 66.5
Functional Fitness						
Chair Stand Test (# in 30 s)	59	11.5 ± 2.7	68	12.5 ± 3.2	127	12.0 ± 3.0
Arm Curl Test (# in 30 s)	59	14.1 ± 4.1	69	14.4 ± 4.1	128	14.3 ± 4.1
Physical Performance Test (out of 36)	59	33.2 ± 2.1	69	33.6 ± 2.4	128	33.4 ± 2.4
Timed Stair Climb Test (s)	58	4.6 ± 1.1	67	4.4 ± 1.10	125	4.5 ± 1.1
Health Status						
SF-12 Physical (PCS-12; arbitrary units)	53	47.3 ± 8.0	63	46.9 ± 9.1	116	47.1 ± 8.6
SF-12 Mental (MCS-12; arbitrary units)	53	50.7 ± 8.9	63	52.2 ± 8.6	116	51.5 ± 8.8

*Significant difference between groups; $p<.05$

Table 5.5 Proportion of individuals reporting physical activity participation and average volume of endurance, strength and flexibility activities at 3 and 12 months
(N=172; Adapted from Reeder et al, 2008)[29].

	3-months			12-months		
Activity Type	CB	HB	Overall	CB	HB	Overall
Endurance						
n (%)	67 (79.8)	74 (84.1)	141 (82.0)	54 (64.3)	58 (65.9)	112 (65.1)
Activity volume[a] (min/wk)	140.0±110.5	169.5±118.1	155.0±115.2	122.6±123.1	185.9±149.0*	155.4±140.2
Strength						
n (%)	64 (76.2)	74 (88.1)	138 (80.2)	54 (64.3)	60 (68.2)	114 (66.3)
Activity volume[a] (min/wk)	30.7±32.9	31.4±53.5	31.1±45.0	31.4±43.1	30.7±56.4[†]	31.1±50.4
Flexibility						
n (%)	65 (77.4)	74 (84.1)	139 (80.1)	53 (63.1)	60 (68.2)	113 (65.7)
Activity volume[a] (min/wk)	32.3±63.2	28.6±60.2	30.3±61.4	31.5±89.1	31.5±89.1	35.3±104.9

[a] Duration of activities is mean±*SD*
* Significantly different than CB group (p<.05)
[†] Significantly different than 6 months

The baseline physician services utilization and cost data for both general practitioners and specialists are presented in Table 5.6. There were no significant differences between the CB and HB groups across any health services utilization variable in the year prior to enrolment in the 50+ *in motion* study. In the year prior to enrolment in the 50+ *in motion* study (baseline), 98% of participants saw a GP physician at least once and 81% had at least one visit to a specialist physician. Participants in both intervention groups averaged approximately 6 GP visits and 3 specialist visits in the baseline year. Approximately 14% of CB participants and 19% of HB participants were classified as frequent users of GP services, while 17-19% of participants (CB =16.9%; HB=18.8%) were frequent users of specialist services. The annual cost of GP services was slightly higher in the HB group compared to the CB group ($206 ± $144 vs. $175 ± $125, respectively) in the baseline year. In contrast, the annual cost of specialist physician services was higher among participants in the CB compared to the HB group ($386 ± $954 vs. $275 ± $355, respectively).

Table 5.6 Comparison of baseline physician services utilization and costs between class-based and home-based intervention groups

	Class-based *n*=59	Home-based *n*=69	Overall N=128
General Physician Services			
# of visits (Mean ± SD)	5.8 ±4.2	6.4 ±4.3	6.1 ± 4.3
	n (%)	*n* (%)	*n* (%)
Frequent user (≥ 10 visits/yr)			
Yes	8 (13.6)	13 (18.8)	21 (16.4)
No	51 (86.4)	56 (81.2)	107 (83.6)
Annual costs (Mean ± SD)	$174.94 ± $124.24	$206.24 ± $143.85	$191.81 ± $135.56
Specialist Physician Services			
# of visits (Mean ± SD)	3.4 ± 2.9	3.2 ± 3.4	3.3 ± 3.1
	n (%)	*n* (%)	*n* (%)
Frequent user (≥ 6 visits/yr)			
Yes	10 (16.9)	13 (18.8)	23 (18.0)
No	49 (83.1)	56 (81.2)	105 (82.0)
Annual costs (Mean ± SD)	$386.20 ± $954.10	$275.40 ± $354.52	$326.47 ± $697.19

Note: All data are mean ± SD unless otherwise indicated. All costs are in 2008 dollars
*Significant difference between groups (p<.05)

Baseline hospital-related utilization and cost data are presented in Table 5.7. Fewer than 15% of 50+ *in motion* participants were admitted to hospital in the baseline year and the majority of admissions were classified as day surgeries. By admission type, 10% of CB and HB participants had at least 1 day surgery hospital admission while approximately 5% (5.1% vs. 4.3%, CB and HB respectively) were admitted as an inpatient. Participants with an inpatient admission spent an average of 1.8 nights in hospital in the baseline year (2.0 ± 1.73 vs. 1.7 ± 0.58 nights for CB and HB, respectively).

There were also no significant baseline differences in hospital costs between intervention groups. Total hospital costs (day surgery + inpatient) were, on average, less than $200 in the baseline year in both intervention groups. When averaged across hospitalized participants, total hospital costs were $1,460.51 ± 992.65 (mean±SD) in the baseline year.

Table 5.7 Comparison of baseline hospital services utilization and costs between class-based and home-based intervention groups

	Class-based *n*=59	Home-based *n*=69	Overall N=128
Hospital Services			
Admitted to hospital	*n* (%)	*n* (%)	*n* (%)
No	51 (86.4)	60 (87.0)	111 (86.7)
Yes	8 (13.6)	9 (13.0)	17 (13.3)
Admission type	*n* (%)	*n* (%)	*n* (%)
Day Surgery	6 (10.2)	7 (10.1)	13 (10.2)
Inpatient	3 (5.1)	3 (4.3)	6 (4.7)
	mean ± SD	mean ± SD	mean ± SD
# of hospital admissions	0.17 ± 0.46	0.16 ± 0.44	0.16 ± 0.45
# of hospital nights[a]	2.0 ± 1.73	1.7 ± 0.58	1.8 ± 1.17
Annual total costs	$198.72 ± $603.99	$189.92 ± $618.95	$193.97 ± $609.71

Note: All costs are in 2008 dollars
[a] Mean nights in hospital based on participants admitted as inpatients (n=6)
*Significant difference between groups (p<.05)

At baseline, general and specialist physician services utilization in both intervention groups was higher than that reported by the general Canadian population (see Table 5.8). A greater proportion of 50+ in motion participants were classified as frequent users of GP and specialist physician services compared to the Canadian population. In contrast, a lower proportion of 50+ *in motion* participants were admitted to hospital overnight and those admitted spent fewer nights in hospital than the general population.

Table 5.8 Health services utilization among Canadians aged 50 years and older[a]

	50 – 64 Yrs. (*n*=29 914)	65 – 79 Yrs. (*n*=20 183)	≥ 80 Yrs. (*n*=6 555)	Overall (*N*=56 652)
GP Consultations				
Mean (SD)	3.2 (4.07)	3.9 (4.28)	4.9 (4.89)	3.8 (4.38)
	%	%	%	%
Frequent user (≥ 10 visits/yr)				
Yes	7.4	10.8	17.2	9.3
No	92.6	89.2	82.8	90.7
[b]*Specialist Consultations*				
Mean (SD)	0.9 (1.97)	0.9 (1.84)	0.8 (1.78)	0.8 (1.84)
	%	%	%	%
Frequent user (≥ 6 visits/yr)				
Yes	2.6	2.1	1.7	2.4
No	97.4	97.9	98.3	97.6
Overnight hospital admission in past year				
Yes	6.8	11.9	17.9	9.8
No	93.2	88.1	82.1	90.2
Total number of hospital nights				
Mean (SD)	6.9 (7.88)	8.2 (9.04)	10.4 (10.01)	8.5 (9.13)

Sample sizes are unweighted. Weighted means and proportions are reported. Rows and columns may not add up to 100% due to rounding and/or missing observations.

[a] Data source: Canadian Community Health Survey, Cycle 3.1. Public Use Microdata File
[b] Specialist consultations include all specialist physicians except eye specialists

5.3.2 Longitudinal analyses

Descriptive data pertaining to the 50+ *in motion* intervention fitness outcomes are presented in Table 5.9. Fewer than 5% of participants missed the follow-up fitness assessment at the Yr.1 follow-up. In Yr. 2, this increased to more than 25% and in the last two years (Yr.3-Yr.4), almost half of participants were not followed up. Three participants died during the study follow-up period – one CB participant in Yr. 3 and two HB participants in Yr. 4. A fourth participant died in the fifth year following the intervention. A brief description of overall changes in the fitness outcomes follows in the next paragraph. Detailed figures, including information about within-group differences, are provided for all intervention outcome variables in Appendix C-1.

After adjusting for missing data, there were no significant differences between the CB and HB group on any of the fitness outcomes during the 4-year follow-up period. Mean arterial blood pressure was significantly lower at Yr.1 ($p<.01$) compared to baseline. At Yr.4, MAP remained lower than baseline level; however not significantly so ($p<.089$). Overall, BMI remained relatively stable over the follow-up period in both groups, while waist circumference declined slightly from baseline through to Yr. 3 ($p<.05$ at Yr.2; $p<.01$ at Yr. 3) after which it returned to baseline levels. Performance on the 6MWT was improved over baseline levels throughout the follow-up period, particularly at Yr.1 and Yr. 2 ($p<.001$ for both). All aspects of functional fitness, improved between baseline and Yr.1 of the intervention ($p<.001$ except PPT score where $p=.076$) and remained stronger than baseline levels throughout the follow-up period. There was little change in either the physical or mental component of the SF-12 from baseline to the end of the follow-up period. At the Yr.1 follow-up, level of physical activity was close to the baseline level. At the Yr.2 follow-up, it had increased significantly over baseline levels ($p<.05$) but by Yr.4, had returned to baseline levels. Sedentary time did not change significantly between baseline and Yr.4.

Table 5.9 Descriptive analysis of 50+ *in motion* intervention outcomes for each study time point (N=128)

		Time Point									
		Baseline (N=128)		**Year 1** (N=123)		**Year 2** (N=93)		**Year 3** (N=63)		**Year 4** (N=62)	
		n	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**
Blood Pressure											
Mean Arterial Pressure (mmHg)	CB	59	95.5 ± 10.06	57	92.5 ± 11.29	40	91.5 ± 10.55	24	92.1 ± 11.88	28	91.9 ± 8.77
	HB	69	97.0 ± 9.92	66	92.6 ± 9.74	51	93.0 ± 10.50	39	92.1 ± 10.19	34	92.2 ± 10.26
Body Composition											
Body Mass Index (kg/m^2)	CB	59	30.1 ± 4.45	57	30.1 ± 4.62	40	29.1 ± 4.04	24	29.4 ± 3.48	28	29.2 ± 4.32
	HB	69	30.6 ± 4.24	66	30.1 ± 4.24	51	31.2 ± 4.53	39	30.8 ± 4.03	34	31.5 ± 4.70
Waist Circumference (cm)	CB	59	98.4 ± 11.93	57	97.9 ± 12.89	40	94.3 ± 11.99	24	94.8 ± 10.60	28	97.6 ± 12.38
	HB	69	99.3 ± 14.54	66	97.1 ± 13.56	51	97.6 ± 13.75	39	95.8 ± 12.04	34	100.9 ± 12.72
Physical Activity											
PASE Score	CB	58	121.7 ± 58.32	56	119.3 ± 59.28	40	141.0 ± 74.12	24	117.6 ± 60.69	27	112.1 ± 58.66
	HB	68	138.5 ± 70.40	65	147.6 ± 71.66	53	141.2 ± 74.81	36	144.6 ± 65.08	33	123.2 ± 62.22
Sedentary Time (hr./wk)	CB	54	16.1 ± 8.55	57	14.5 ± 8.68	38	16.3 ± 9.20	24	15.5 ± 8.65	27	18.4 ± 9.61
	HB	67	18.1 ± 8.90	66	15.6 ± 8.63	51	18.6 ± 9.60	37	14.7 ± 8.17	33	17.0 ± 9.09
Cardiorespiratory Endurance											
6-Minute Walk Test (m)	CB	58	546.0 ± 69.75	57	583.7 ± 91.84	39	596.1 ± 82.02	23	581.3 ± 93.47	28	577.8 ± 92.2
	HB	69	561.5 ± 63.30	66	591.8 ± 77.66	49	585.1 ± 80.79	39	558.5 ± 82.07	34	552.7 ± 80.4
Functional Fitness											
Chair Sit to Stand Test (# in 30s)	CB	59	11.5 ± 2.67	57	14.8 ± 4.28	40	14.7 ± 5.12	24	14.9 ± 5.68	28	14.9 ± 4.95
	HB	68	12.3 ± 3.53	66	15.1 ± 4.48	50	14.2 ± 4.47	39	14.0 ± 3.49	34	13.9 ± 3.14
Arm Curl Test (# in 30s)	CB	59	14.1 ± 4.11	57	16.6 ± 4.81	40	16.9 ± 4.91	24	19.5 ± 5.99	28	18.6 ± 6.23
	HB	69	14.4 ± 4.09	66	16.7 ± 5.41	50	17.2 ± 5.15	39	18.2 ± 5.90	34	17.0 ± 7.30
Timed Stair Climb (sec)	CB	58	4.6 ± 1.06	55	3.9 ± 1.21	39	4.1 ± 0.94	22	4.4 ± 1.57	27	6.6 ± 2.87
	HB	67	4.4 ± 1.13	64	3.8 ± 1.44	47	4.0 ± 1.14	38	4.2 ± 1.15	34	5.6 ± 2.06

*Significant difference between groups at baseline (p<.05); CB=class-based; HB= home-based

Table 5.9 continued

		Time Point									
		Baseline (N=128)		**Year 1** (N=123)		**Year 2** (N=93)		**Year 3** (N=63)		**Year 4** (N=62)	
		n	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**	***n***	**Mean ± SD**
Physical Performance Test (out of 36)	CB	59	33.2 ± 2.14	57	33.9 ± 3.51	39	34.7 ± 1.46	24	34.0 ± 3.14	27	34.2 ± 1.45
	HB	68	33.6 ± 2.58	66	34.4 ± 2.16	50	34.0 ± 3.01	39	34.3 ± 2.32	33	34.1 ± 1.53
Health Status											
SF-12 Physical	CB	53	47.3 ± 8.01	55	47.4 ± 8.77	39	47.7 ± 8.23	20	50.0 ± 9.05	26	46.4 ± 9.78
	HB	63	46.9 ± 9.08	64	47.6 ± 8.98	53	46.4 ± 10.76	37	47.9 ± 8.65	32	47.1 ± 11.14
SF-12 Mental	CB	53	50.7 ± 8.92	55	54.2 ± 8.95	39	54.2 ± 7.89	20	52.8 ± 10.15	26	54.5 ± 7.46
	HB	63	52.2 ± 8.63	64	52.7 ± 8.07	53	53.2 ± 9.70	37	53.3 ± 7.82	32	52.1 ± 9.99

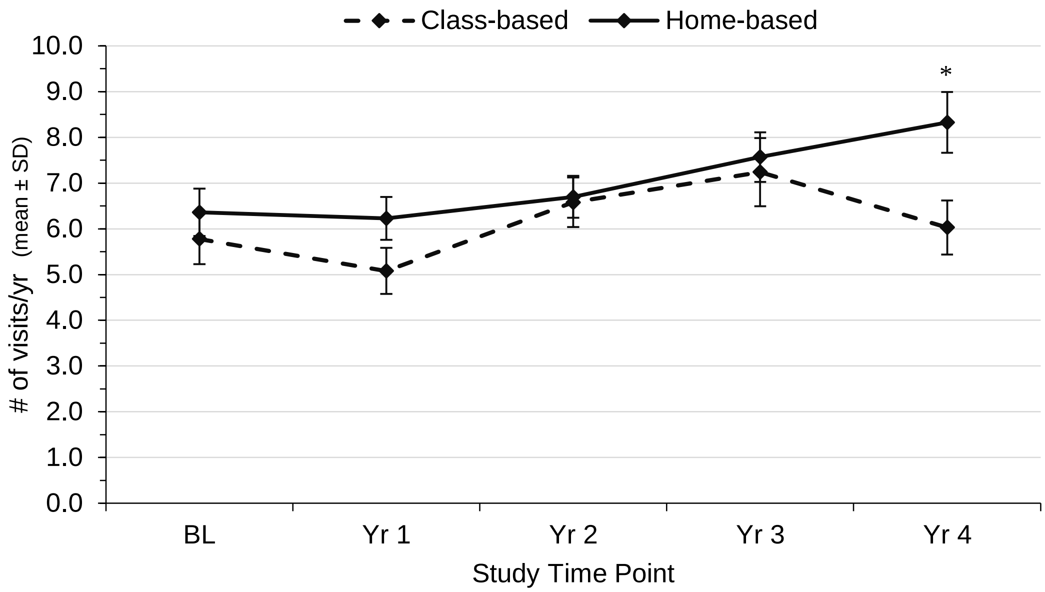
*Significant difference between groups at baseline (p<.05); CB=class-based; HB= home-based

Results of the longitudinal analyses of the health services utilization and cost outcomes are presented separately for each dependent variable according to category of services (GP physician, specialist physician, and hospital services).

General Physician Services

The use of GP services in each study year is presented in Figure 5.3. Visits to GP physicians increased by approximately 1 visit over the course of the study period, from an average of 6.1 visits in the baseline year to 7.2 visits in Yr. 4. Overall, the adjusted analyses showed the number of GP visits to be significantly higher in Yr.2 and Yr.3 (p<.01) compared to baseline but not at Yr.4. Although the HB group had more GP visits than their CB counterparts throughout the follow-up period, there was no significant difference between groups until Yr. 4 when the number of annual GP visits increased in the HB group and decreased in the CB group such that GP visits were approximately 60% higher in the HB group compared to the CB group (IRR_{adj}=1.61; p=.01).

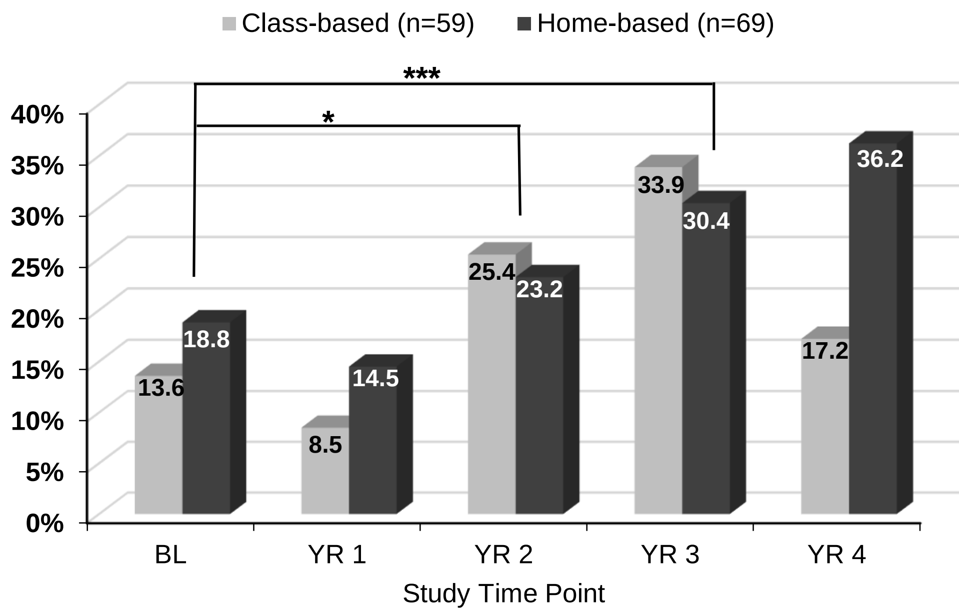
In the adjusted analyses, the number of GP visits was most strongly associated with the number of chronic conditions, with each additional condition resulting in an 11% increase in annual visits (IRR_{adj}=1.11; p=.001). Cardiovascular endurance (IRR_{adj}=1.00; p=.395), lower body strength and endurance (as measured by the Chair Sit to Stand Test; IRR_{adj}=0.99; p=.332) and self-reported physical health (SF-12-Physical; IRR_{adj}=0.99; p=.072) were retained as confounders in the final statistical model (Tables C.1 – C.2 in Appendix C-2).



Variables retained in the final analytical model include: missing data; chronic condition index; SF-12 Physical health; CV endurance, Chair Sit to Stand Test (see Appendix C-2)
* Significant group x time interaction (p=.01)

Figure 5.3 Annual number of general physician visits over the 5 year study period, by intervention group (unadjusted mean ± SE)

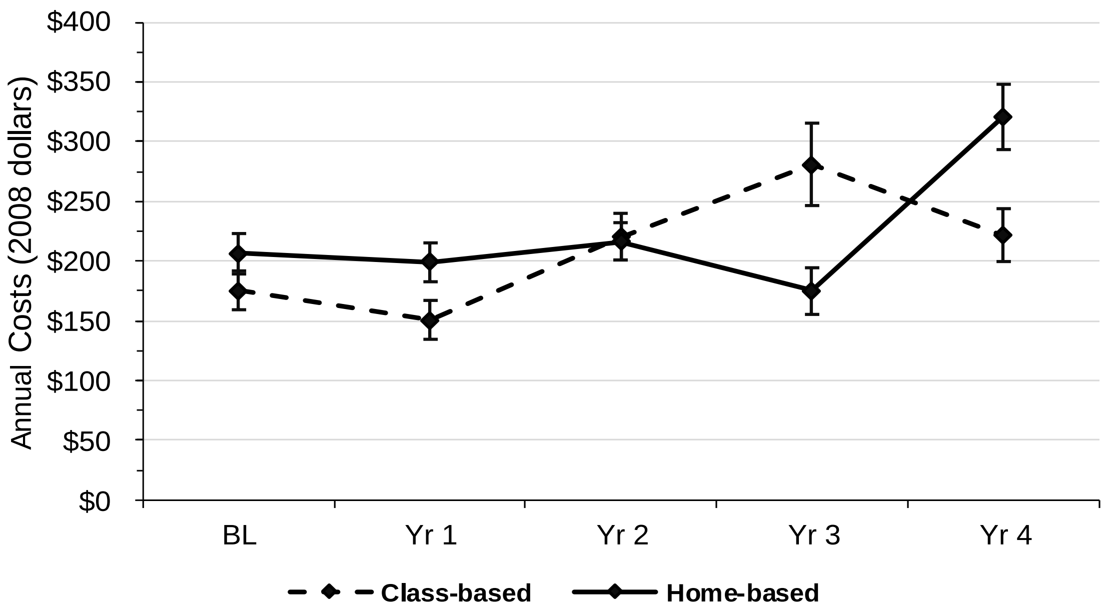
The proportion of 50+ *in motion* participants classified as frequent users (>10 visits/yr.) of GP services in each study year is shown in Figure 5.4. The proportion of participants who were classified as frequent users of GP services decreased from 16% at baseline to 11% in the first year of the follow-up period. Subsequently, frequent use of GP services in Yr. 2 (24%) and Yr.3 (32%), was significantly higher than at baseline ($p<0.05$ and $p<0.001$, respectively). Year 4 saw the proportion of frequent users drop by 5%, mostly in the CB group. Frequent use of GP services did not differ significantly between the CB and HB groups ($p=.348$), nor was there a significant group x time effect ($p=.100$). Participants were more likely to be frequent users of GP services if they reported more chronic conditions (OR_{adj}=1.23; p<.05) while those with better CV endurance (OR_{adj}=0.996; p=.059) and better self-reported physical health (OR_{adj}=0.97; p=.059) were less likely be frequent users of GP services (Tables C.3 – C.4 in Appendix C-2).



Analyses adjusted for missing data, post-secondary education (yes/no); chronic condition index; SF-12 Physical Composite Score; CV endurance (see Appendix C-2)
* Significantly different than baseline (*p*<.05)
*** Significantly different than baseline (*p*<.001)

Figure 5.4 Proportion of 50+ *in motion* participants classified as frequent users (>10 visits/yr.) of GP services.

Total costs associated with the use of GP physician services over the study time period are shown in Figure 5.5. Over the 5-year study period, annual GP physician costs increased by less than $100, with adjusted analyses (of log-transformed costs) showing no significant differences between intervention groups (β=0.065; *p*=.214, HB compared to CB) or study year (p=.675). After adjusting for confounders, including the number of GP visits, age, household income, number of chronic conditions, PCS-12 score, and measures of functional fitness, CV endurance was significantly positively associated with costs associated with GP visits (B=.001, $p<.05$; (Tables C.5 – C.6 in Appendix C-2).

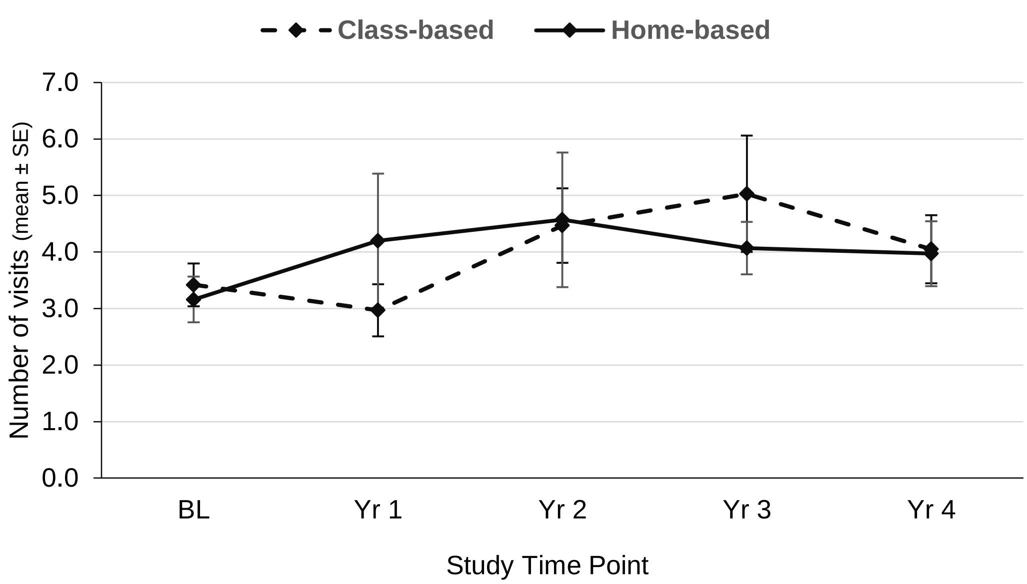


Variables retained in the final analytical model include: missing data, age, household income (<$30,000K – yes/no); chronic condition index; SF-12 Physical Composite Score; CV endurance, Chair Sit to Stand Test and Timed Stair Climb (see Appendix C-2)

Figure 5.5 Annual costs of general physician services over the 5 year study period, by intervention group (unadjusted mean ± SE)

Specialist Physician Services

The number of visits to specialists in each study year is presented in Figure 5.6. The majority (~80%) of 50+ *in motion* participants saw a specialist physician at least once each year including the baseline year but the odds of seeing a specialist did not increase over time (OR_{adj}= 0.649 – 2.448 compared to baseline; $p>.05$). The odds of seeing a specialist were lower for participants in the HB group compared to their CB counterparts; however this was not statistically significant (OR_{adj}= 0.887; p=.825). Indicators of health need such as visits to GP physicians (OR_{adj}= 1.246; p<.01) and number of chronic conditions (OR_{adj}= 1.834; p<.001) were strongly associated with the incidence of a visit to a specialist. Lower body strength and endurance, as measured by the Chair Sit to Stand Test, was negatively associated with specialist visits (OR_{adj}= 0.869; p<.01), even after adjusting for GP visits, chronic conditions, income and SF-12 physical health status (Tables C.7–C.8 in Appendix C-2).



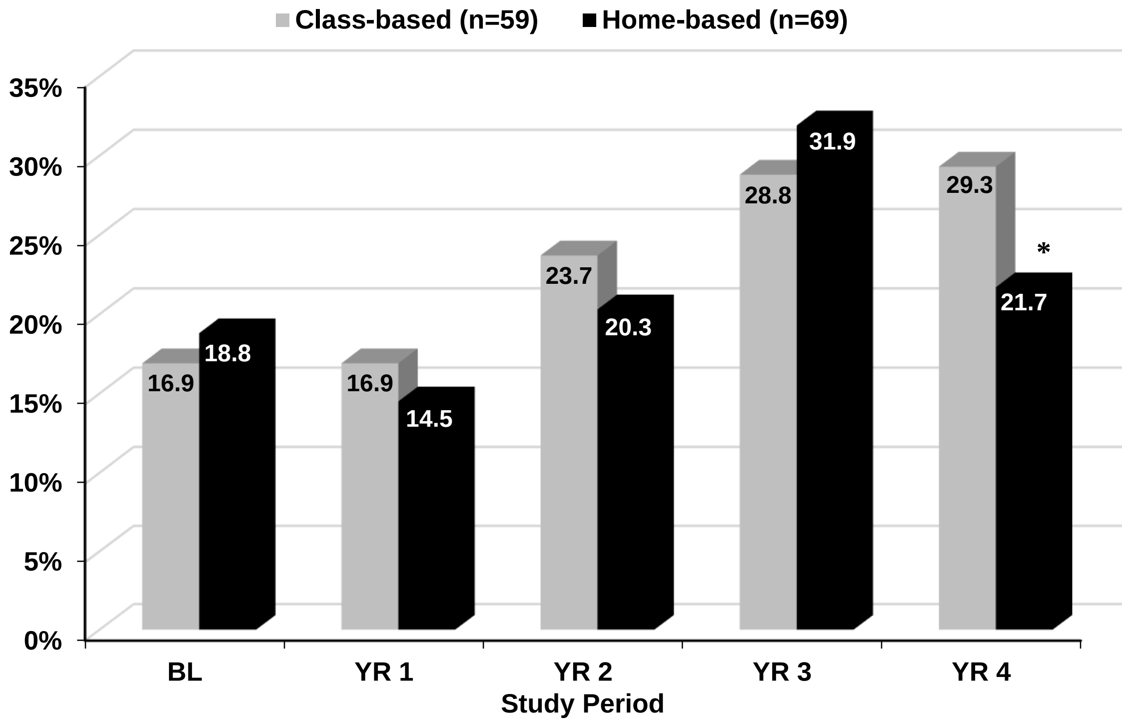
Variables retained in the final analytical model include: missing data; age; gender; number of GP visits; chronic condition index; SF-12 Physical Composite Score; physical activity; sedentary time; CV endurance; Chair Sit to Stand Test; Timed Stair Climb (see Appendix C-2).

Figure 5.6 Annual number of specialist physician visits over the 5 year study period, by intervention group (unadjusted mean ± SE)

Over the course of the study period, there were no significant differences between the CB and HB groups in the number of specialist visits. Overall, participants made approximately 3.5 visits to a specialist physician at baseline and Yr. 1 (3.3 visits and 3.6 visits, respectively). In the next two years, the number of visits to specialist physicians increased, averaging 4.5 visits in Yr. 2 and Yr. 3. In Yr. 4, visits to specialist physicians dropped by approximately 0.5 visits. The multivariate analysis revealed a significant group by time interaction in Yr.3, indicating a greater rate of change in specialist visits in the HB group in this year (IRR_{adj}=2.014, p=.016).

Visits to specialist physicians were significantly associated with the number of GP visits (IRR_{adj}=1.10; p<.001) and the number of chronic conditions (IRR_{adj}=1.10; p=.01). Age was positively associated with visits to specialists (IRR_{adj}=1.02; p<.05) and women had, on average, 57% more specialist visits than men (IRR_{adj}=1.57; p<.01). CV endurance, and measures of functional fitness were also significantly associated with the number of visits to specialists. Better performance on the 6MWT was associated with a slightly greater rate of specialist visits (IRR_{adj}=1.002; p<.05). A stronger score on the Chair Sit to Stand test was associated with fewer specialist visits (IRR_{adj}=0.94; p<.01) while poorer performance on the Timed Stair Climb was associated with more specialist visits (IRR_{adj}=1.08; p<.05; see Appendix C-2, Tables C.9–C.10).

The proportion of 50+ *in motion* participants classified as frequent users (>6 visits/yr.) of specialist physician services in each study year are shown in Figure 5.7. The odds of being a frequent user of specialist visits were approximately 41% higher at Yr.4 than at baseline (p<.05). A significant group x time interaction in Yr.4 showed HB participants to be 90% less likely to be frequent users of specialist services (OR_{adj}=0.100; p<.05) than their CB counterparts. Participants were more likely to be frequent users of specialist physician services if they had more GP visits (OR_{adj}=1.17; p<.001), reported more chronic conditions (OR_{adj}=1.49; p<.05), attained post-secondary education (OR_{adj}=3.28; p=.052) while those earning more than $30,000/yr were less likely to be a frequent user of specialist services (OR_{adj}=0.34; p<.01). Both BMI and waist circumference were significantly, but oppositely, associated with frequent use of specialist services. The likelihood of being a frequent user of specialist services increased significantly as BMI increased (OR_{adj}=1.17; p<.05) while waist circumference was negatively associated with frequent use of specialist services (OR_{adj}=0.96; p<.05). Physical activity, sedentary time, CV endurance, and measures of functional fitness were retained in the final model as confounders but were not significantly associated with frequent use of specialist services (Tables C.11–C.12 in Appendix C-2).

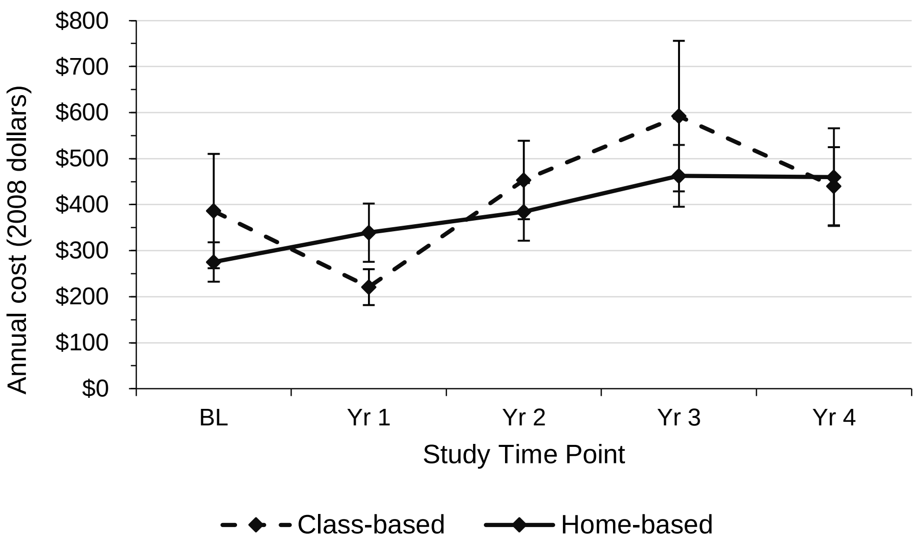


Analysis adjusted for missing data, age; household income; education; chronic condition index; SF-12 Physical Composite Score; physical activity; CV endurance; Chair Sit to Stand Test; Timed Stair Climb; Body Mass Index; Waist circumference (see Appendix C-2).
* Significant group x time interaction (*p*<.05)

Figure 5.7 Proportion of 50+ *in motion* participants classified as frequent users (>6 visits/yr.) of specialist physician services.

Total costs associated with the use of specialist physician services over the study time period are shown in Figure 5.8. Over the 5-year study period, annual costs associated with specialist physician services increased by approximately $125, with adjusted analyses showing no significant differences in log-transformed costs between intervention groups (β=0.015; *p*=.923, HB compared to CB) or study year (*p*=.100). After adjusting for confounders, including the number of visits to GP and specialist physicians GP visits, age, education level, household income, number of chronic conditions, SF-12 physical health score and the Timed Stair Climb

Test, performance on the Chair Stand Test was significantly negatively associated with costs for specialist services (β= -.054, p<.001; see Tables C.13–C.14 in Appendix C-2).

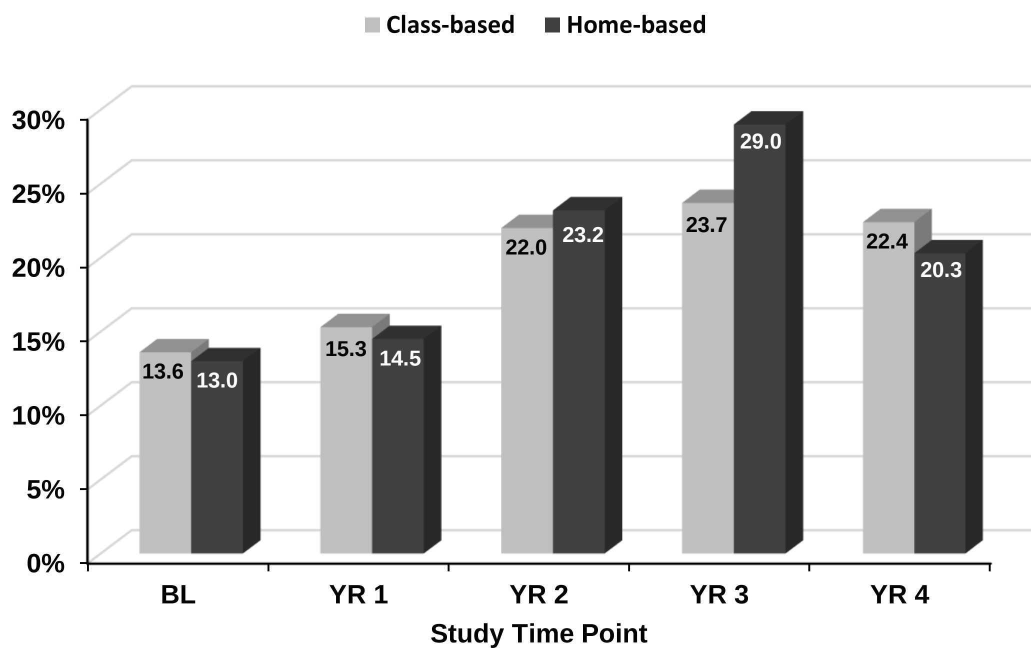


Variables retained in the final analytical model include: missing data, GP visits, specialist visits, age; household income; education level; chronic condition index; SF-12 Physical Composite Score; Chair Sit to Stand Test; Timed Stair Climb (see Appendix C-2).

Figure 5.8 Annual costs of specialist physician services over the 5 year study period, by intervention group (unadjusted mean ± SE)

Hospital Services

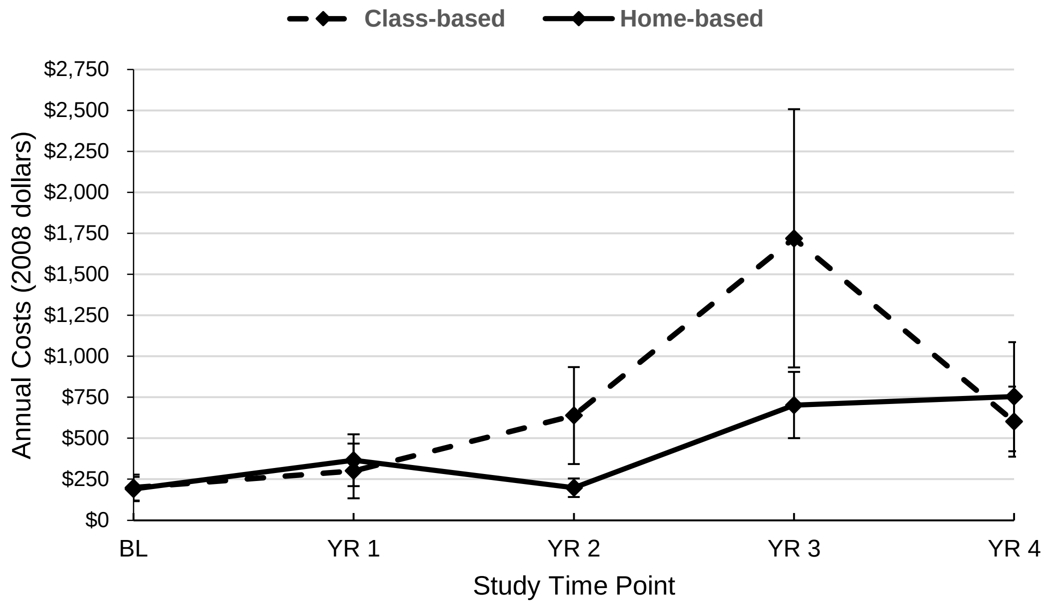
Over the entire study period, 81 of 128 (63.3%) participants were admitted to hospital at least once, with 37/128 (28.9%) of participants having at least one overnight hospitalization and 72/128 (56.3%) with at least one day surgery admission (Figure 5.9). The proportion of participants admitted to hospital increased from approximately 13.5% to 27% between baseline and Yr. 3, after which the proportion decreased to 21% in the final study year; however this was not statistically significant. Likewise, the likelihood of being admitted to hospital did not differ between the CB and HB groups. Better health status, as indicated by the SF-12 physical health component score, was significantly associated with a decreased likelihood of hospitalization (OR_{adj}= 0.960; p<.05) while a higher level of physical activity was associated a slightly greater likelihood of being admitted to hospital (OR_{adj}= 1.005; p=.104), after adjusting for visits to GP and specialist physicians, the number of chronic conditions, education level, sedentary time and functional fitness, as measured by the Timed Stair Climb (Tables C.15–C.16 in Appendix C-2).



Variables retained in the final analytical model include: missing data, GP visits, specialist visits, education level; chronic condition index; SF-12 Physical Composite Score; PASE score and sedentary time (see Appendix C-2).

Figure 5.9 Proportion of 50+ *in motion* participants admitted to hospital over the 5 year study period, by intervention group

Total costs associated with the use of hospital services over the study time period are shown in Figure 5.10. Mean annual total hospital costs (day surgery and inpatient combined, adjusted to 2008 dollars) grew by approximately 500% between baseline and Yr. 3, going from an average of $193 to almost $1200 before dropping by approximately 40% in Yr. 4, to $684. The adjusted analysis of log-transformed hospital costs showed, however, that this was not statistically significant (p=.228). Likewise, log-transformed hospital costs did not differ significantly between groups overall (p=.850), nor was the group x time interaction significant at any time point. After adjusting for confounders, including the number of visits to GP and specialist physicians GP visits, education level, household income, number of chronic conditions, and blood pressure, higher levels of sedentary time (β=0.013, p=.010) and poorer performance of Timed Stair Climb Test (β=0.083, p<.05) were significantly associated with higher total hospital costs, as was a higher SF-12 physical component score (β= 0.014, p<.05). Higher levels of physical activity were associated with lower hospital costs (β= -0.001) while blood pressure was negatively associated with total hospital costs (β= -0.008); however neither of these associations were statistically significant (p=.074 and p=.068, respectively; (Tables C.17–C.18 in Appendix C-2).



Variables retained in the final analytical model include: missing data, GP visits, specialist visits, education level; income; chronic condition index; SF-12 Physical Composite Score; MAP; PASE score; Sedentary time; Timed Stair Climb (see Appendix C-2).

Figure 5.10 Annual total hospital costs over the 5 year study period, by intervention group (unadjusted mean ± SE)

5.4 DISCUSSION

The 50+ *in motion* program was a randomized clinical trial to compare the effectiveness of a CB and a HB exercise intervention for older adults with chronic disease risk factors. This study is, to our knowledge, the first Canadian study to examine longer-term effects (beyond 24-months) of a randomized clinical PA intervention the use of physician and hospital services and their associated costs among community-dwelling older adults.

For the most part, the use of health services by participants in the 50+ *in motion* intervention remained relatively stable over the 5-year study period. While participants' use of GP physician services was higher in Yr. 2 and Yr. 3, by Yr. 4 it was not significantly different than baseline levels. The odds of seeing a specialist did not significantly change from baseline to the end of the follow-up period, nor did the annual number of visits to specialists or the use of hospital services. The odds of being a frequent user of GP physician services were approximately 40% higher at Yr. 4 compared to baseline; for specialist physicians, the likelihood of being a frequent user increased by almost 5-fold. Nonetheless, health care costs, regardless of the source, did not significantly increase above baseline levels throughout the study period.

In a group of older adults, the majority of whom have multiple chronic conditions, the maintenance of baseline levels of utilization of most types of health services, including hospital services, as well as all health care costs over a 5-year period should be viewed as a positive finding. This is somewhat consistent with previous findings where exercise seemed to prevent further increases in health services utilization and costs, rather than lead to any immediate reductions.[24,28] However, for ethical reasons our study did not include a non-exercising control group, making it difficult to determine with a high level of certainty whether or not the 50+ *in motion* intervention had a similar effect.

There appeared to be little difference between the two programs in terms of their effects on long-term health services utilization and costs, with two exceptions. First, although participants in the HB group had more GP visits than their CB counterparts throughout the study period, this difference was not significant until the final year of the study where the annual number of GP visits was 60% higher in the HB group, after adjusting for health status, the number of chronic conditions, CV endurance, functional fitness and self-rated physical health status. This difference in GP physician utilization did not, however, result in significantly higher costs in the HB group nor did it result in any differences in the odds of being a frequent user of GP services between the two groups. This finding is in contrast to those of Ackermann et al, (2008) who compared changes (over a shorter time frame) in annual primary care visits between Medicare enrollees who participated in a class-based exercise program similar to the 50+ *in motion* program and matched controls.[26] In that study, exercise program participants had more primary care visits and higher primary care costs than controls, leading the authors to suggest that participants who seek out more healthcare contacts may be more motivated to comply with medical treatments and undertake healthy lifestyle changes, including increasing PA.[26] Given that HB group in the 50+ *in motion* study was not a control group but another intervention group, it is unlikely that participants in either of the intervention groups were any more or less motivated to undertake healthy lifestyle changes, considering that they all volunteered to participate in the study. However, it is possible that as a whole, the 50+ *in motion* intervention population were more motivated than the general older adult population to seek more physician services, given that they had higher rates of both GP and specialist services utilization than those reported by the representative, population-based sample of older Canadians in Study 1.

The second aspect of health services utilization where the CB and HB groups differed was related to frequent use of specialist services. In Yr.3, the proportion of frequent users was 70% higher than baseline in the both groups but in Yr.4, the proportion of frequent users in the HB group dropped to a level that was just 15% higher than baseline. Meanwhile, in the CB group, there remained more than 70% more frequent users than at baseline. Frequent users of physician services most often carry a greater burden of morbidity, resulting in a greater need for healthcare.[44,62] While the analysis was adjusted to account for differences in morbidity in several ways – the number of visits to GP physicians, the number of chronic conditions and health status/health-related quality of life – it is possible that unobserved differences in health between the two groups may have emerged during the study follow-up period. Our findings partially support those of Nguyen et al (2008) who, in another study of Medicare enrollees' use of a class-based PA health benefit, found that health benefit participants made more visits to specialists than controls, even after adjusting for health status and chronic disease burden.[27] However, participation in the PA benefit was also significantly associated with higher specialist costs than controls whereas in our study, the higher proportion of frequent users of specialist services in the CB program did not result in higher specialist costs. Since we did not consider different physician specialties in our analysis, it is possible that there were differences between the CB and HB groups in the types of specialists consulted, which may have had a bearing on the associated costs. Until now, frequent use of physician services, regardless of physician type, has not been examined with regards to physical activity or exercise interventions. This pattern of health services utilization does, however, have important implications for the provision of health services, when one considers that the majority of health services utilization and costs are incurred by a relatively small proportion of the population.[2] Thus, improving our understanding of so-called ‘conspicuous consumers’ of health services and the factors associated with frequent use of physician services will provide much needed information on how best to plan for and address this issue going forward.

There are just three Canadian studies examining the effects of exercise interventions on health services utilization and health care costs, albeit coming from a cost-effectiveness perspective. Davis and colleagues examined the effects of separate interventions resistance training and resistance training and aerobic training in community-dwelling women and in each instance, found that total healthcare costs (based on visits to health professionals, hospital services utilization, and laboratory and diagnostic testing) were significantly lower in the intervention groups compared to a balance and toning control group.[21-23] They further reported that, in the case of the 12-month resistance training study, the cost benefits of participating were sustained through a period of 21 months even though the health benefits of participation were not.[21] The results of the present study provide some support for these findings. Although not statistically significant, the mean healthcare costs associated with GP and specialist physician utilization decreased by 8% and 13%, respectively, in the first follow-up year of the 50+ *in motion* intervention. By contrast, however, mean hospital costs increased by approximately 75% ($194 CAD to $335 CAD) in the same time frame. Nonetheless, together these studies provide early evidence of the promise of PA intervention strategies to maintain or reduce the levels of health services utilization and healthcare costs among older adults.[22] As expected, the most consistent determinants of health services utilization and costs over the 4-year follow up period were those related to health status and health need.[48] After adjusting for comorbidity, physician contacts, and other covariates, physical health status (as measured by the SF-12) was significantly associated with both hospital admissions and hospital costs. A single point increase in the PCS-12 score, indicating better physical health, was associated with a 4% decrease in odds of being admitted to hospital. However, hospital costs increased by 1.4% for every 1-point increase in PCS-12 score, which is contrary to the negative association consistently reported in the literature. While this was unexpected, differences in study populations and/or methodologies may partly explain our findings. In this study day surgery and inpatients hospital costs were aggregated together whereas other studies often consider inpatient and outpatient costs separately, and in the case where hospital data is self-reported, whether or not the respondent includes day surgery and/or inpatient data depends largely on how clearly and specifically they are instructed to do so.

While not significantly associated with any measures of physician services utilization or costs, the PCS-12 score was retained in all statistical models as a confounding variable. Interestingly, the MCS-12 score was not associated with any measure of health services utilization or health care costs. This would seem to suggest that physical health status is a more important or relevant determinant of health services utilization than mental health status; however the literature indicates this is not necessarily the case. A recently published systematic review of health service use and costs found that depression was linked with increased health services utilization in all included studies, and only a small proportion of the increased service use and costs were attributable to depressive symptom treatment.[63] In addition, Denkinger et al (2012) reported an association between loneliness and the use of physician services but not length of hospital stays in a population-based cohort study of older adults in Germany. The SF-12 derives the PCS-12 and MCS-12 scores from separate scoring algorithms based on the same 12 items on the instrument, which reflect not only health status, but also well-being and attitudes and perceptions about one's health. It is possible that the PCS-12 scores reflected, to some degree, aspects mental health in addition to physical health, which may explain why it emerged as a stronger correlate of health services utilization and costs in this study.

After adjusting for health status/need, fitness-related variables such as CV endurance and functional fitness were more consistently and/or more strongly associated with HSU and HCC than either PA or body composition. Given that CV endurance and functional fitness are measures of physiological function, this was not necessarily an unexpected finding. However, the associations between these fitness-related variables and the dependent variables were not always as expected in terms of strength or direction, suggesting that relationships between PA, health-related fitness and health services utilization and costs may be more complex than previously assumed.[64] For example, higher CV endurance was associated with a decreased likelihood of being a frequent user of GP services (a decrease of ~4% for every 100 metres covered in the 6MWT) but the lack of a significant association between CV endurance and hospital services utilization and costs was contrary to what was hypothesized. Furthermore, CV endurance was significantly associated with GP physician costs, but the strength of the association was relatively weak. The association between CV endurance and frequent use of GP services in the present study is in contrast to Petrella et al (1999), who found that CV fitness was not significantly associated with GP physician contact over a 12-month period in a group of community dwelling older adults.[65] In the present study, findings of relatively weak or non-significant associations between CV endurance may be partially explained by method by which it was assessed. While the 6MWT is a valid and frequently administered test to assess CV endurance, particularly in clinical populations, it is an indirect assessment of CV endurance and thus, lacks the precision of directly measured CV performance. This makes interpretations of the results more difficult and the possibility that the associations are underestimated and/or blunted more likely. Additional research with direct measures of CV fitness would likely help to clarify these associations.

Based on the estimates of the economic burden of obesity published by Katzmarzyk and Janssen (2004), it was hypothesized that BMI and WC would be significantly associated with all health services utilization and cost variables.[12] Interestingly, BMI and WC were independently associated with only one health services outcome, that being frequent use of specialist services. As was hypothesized, participants with higher BMIs were significantly more likely to be a frequent user of specialist physician visits. Waist circumference, however, was negatively associated with frequent use of specialist services, meaning that participants with a higher WC were less likely to be frequent users of specialist services. This is inconsistent with other findings in the literature which report that abdominal obesity (WC> 102cm in men and >88cm in women) to be positively associated with greater use of GP physician services and hospital services.[66] One possible explanation for this finding relates to the so-called 'obesity paradox', a term describing a somewhat consistent finding of improved survival and lower mortality risk in overweight or mildly obese clinical CVD populations.[67,68] It is possible that overweight and obese participants received earlier and more aggressive treatment to mitigate high CV risk, thereby delaying or limiting disease progression and severity, thus reducing their need for frequent specialist care.[68]

Better functional fitness was associated with lower specialist physician utilization, specialist costs, and hospital costs. Higher levels of lower body strength and endurance, as measured by the CSST, were significantly associated with a decreased likelihood of seeing a specialist, fewer specialist visits and lower specialist costs. Faster performance of the Timed Stair Climb Test (TSCT) was also associated with fewer specialist visits, as well as lower hospital costs. Furthermore, at least one functional fitness measure was retained as a covariate in all statistical models except in the case of frequent use of GP services. Both measures of functional fitness reflect one's ability to perform basic activities of daily living, and poor performance on these tests are reflective of diminished overall muscular strength, endurance and power, increasing the risk of falling and frailty, and potentially, the need for specialist care (e.g. orthopedic surgeons).[69] As reported by Reeder et al (2008), the community-dwelling older adults in this study appeared to have few, if any, ADL limitations, so it is telling that measures of functional fitness were so consistently associated with health services utilization, even after adjusting for health status and other covariates.[29] These results suggest that encouraging older persons, regardless of age or health status, to undertake activities to maintain or improve their level of muscular strength and endurance could have an impact on health services utilization, particularly in reducing both the demand for specialist services and the considerable costs that go along with specialist care.

Contrary to our hypothesis, physical activity was not significantly associated with any health services utilization or cost outcomes in any of the adjusted models; however it was retained as a confounder in the final models for outcomes related to the overall use of specialist services, frequent use of both GP and specialist services, hospital admissions and hospital costs. This suggests that the association between PA and health services utilization is primarily indirect, through its effects on physiological function (as indicated by physical fitness) and in turn, health status. Physical activity may also confer health benefits at levels below that needed to result in improvements in physical fitness.[17,70] Accounting for physical fitness in studies of PA and health services utilization helps to clarify the direct effects of PA in the broad sense by accounting for the benefits of physical activity that may be genetically determined (i.e. physical fitness and response to PA/exercise).[71,72] This may be particularly relevant in an older adult population in which survivor bias is not uncommon.

Few studies examining the association between PA and health services utilization have included, let alone adjusted for, measures of physical fitness which makes it difficult to draw comparisons with between studies. As outlined previously, Petrella et al (1999) failed to find significant bivariate associations between physician contacts and either PA or measures of physical fitness in a group of community-dwelling older adults.[65] Likewise, Buchner et al (1999) found no difference in hospitalization rates between exercise and control groups in their study of the effects of strength and endurance training on fall risk and health services use in older adults. They did, however, report that control participants were at higher risk for hospital stays longer than 3 days and suggested that higher levels of physical fitness could lead to shorter hospital stays.[24] Chen et al (2008) also found that self-reported hospitalizations were reduced in an exercise group after a 12-week walking program, but did not consider fitness parameters in their analyses.[28] Larger population-based studies of PA and health services utilization have also consistently reported associations between PA and various health services utilization and cost outcomes, but none of these analyses adjusted for measures of physical fitness.[14,44,73]

Sedentary behaviour, as it pertains to health, is an emerging area in physical activity research. In this study, sedentary behavior was found to be positively associated with hospital costs, after adjusting for physical activity, functional fitness, health status and other potential confounders. This finding is consistent with a growing evidence base suggesting that sedentary behaviour is associated with health, independent of physical activity.[74] To my knowledge, no studies of health services utilization and health care costs to date have considered sedentary behaviour alongside PA; therefore, further research examining these associations are needed before conclusions can be drawn. Nevertheless, it is an important finding that has potential implications for the design and prioritization of public health strategies and therapeutic lifestyle interventions.

There are several limitations that should inform the interpretation of these results. First, ethical considerations precluded the possibility of including a wait-list control group in the study design thereby limiting the conclusions that can be drawn about the effectiveness of the intervention. In an effort to partially address this issue and to gauge the generalizability of the results to the general older adult population, the descriptive physician and hospital services utilization data of the 50+ *in motion* participants were compared to the self-reported health services utilization data from the population-based sample used in Study 1. Rates of physician and specialist services utilization were higher in the 50+ *in motion* participants compared to those of the general older adult population from the CCHS. The differences in physician services utilization may reflect a greater level of morbidity among the older adults in the 50+ *in motion* intervention but it could also be indicative of greater motivation to seek health services, considering that the intervention population had lower rates of in-patient hospital admissions than that reported by the general older adult population.

Secondly, approximately 25% of the original study population (44/172) did not consent to the use of the administrative health data and were therefore not included in this analysis, resulting in a reduction in statistical power. Additionally, the differences between consenters and non-consenters in their baseline mental health status as well as their pattern of participation in the study follow-up may be a potential source of bias in this study.

The use of self-reported measures of PA and sedentary behaviour also leave open the possibility of biased estimates due to inaccurate recall or social desirability. Recently, studies have suggested that the PASE is limited when used in certain patient populations and point to accelerometers as a more precise tool for assessing volume and intensity of PA.[75] Objective measures of physical activity, such as those obtained through accelerometers, overcome the limitations associated with self-report measures of PA and may better measure both sedentary behaviour and PA in older adults, given their greater sensitivity to very light and/or very brief activity.[76] Other potential sources of bias in this study include selection bias and survivor bias.

Health care costs were determined based on health service utilization encounters which were captured in the Saskatchewan Health database. While the costs examined account for two major areas of publicly-funded health care expenditures (physician and hospital services), they represent only a subset of total health care expenditures since costs associated with prescription drugs (and a portion of medical laboratory and diagnostic imaging tests) were not included in this study.

Lastly, although this study is the first to have a follow-up period extending beyond the 24-month period, it is possible that a longer follow-up period, one extending beyond five years, may be necessary to accurately determine the overall impact of PA on HSU and HCC, given the long latency of most chronic conditions and their treatment, at both the sub-clinical and clinical level.

The above limitations notwithstanding, several strengths of this study should be noted. As one of the first prospective, longitudinal studies of the effects of a PA intervention on health services utilization in an older adult population, this study makes an important contribution to the existing literature. The consideration of additional health services utilization outcomes beyond the standard annual rates of visits provides new insights into patterns of health services utilization in the older adult population. Furthermore, the follow-up period considered in this study extends two years, at least, beyond that of other published data, allowing for a more detailed examination of longer-term effects of a PA intervention on health services utilization and costs. The use of comprehensive administrative health data as the source of the health services utilization and costs data reduces the possibility of recall bias in the dependent variables. Lastly, the use of GEE methods and negative binomial models in the statistical approach instill confidence in the robustness of the estimates and the use pattern mixture modeling to adjust for possible differences in the intervention among those lost-to-follow-up further strengthen the statistical rigor of this paper.

In conclusion, the findings of this study suggest that CB and HB physical activity interventions in sedentary older adults are equally effective in preventing increases in health services utilization and health care costs over the long term in community dwelling older adults with chronic conditions. Other considerations, including cost-effectiveness may therefore be needed to fully inform program choice. The provision of home-base programs is thought to be less costly than class-based programs, for both the health care system and individual participants; however, evidence to support this is scarce.[33] Further research is needed to determine if one type of physical activity program is preferable to another from a cost-effectiveness point of view.

Measures of functional fitness emphasizing lower body strength, endurance and power were more consistently associated with lower health services utilization than CV endurance, body composition or physical activity, reiterating the importance of engaging older adults in activities that will help to maintain functional fitness and protect against frailty as they age. This is further reinforced by the association of sedentary behavior with higher hospital costs, independent of physical activity, functional fitness and health status. While further research is needed to corroborate these findings and to further our understanding of the relationships between physical activity and sedentary behaviour, physical fitness, and health services utilization, the key message to older adults is a simple one: move more, sit less and include small physical challenges into every day. Health promotion initiatives targeting older adults to maintain or improve their muscular strength and endurance by being more active throughout their day will have many potential benefits, not the least of which may be to stabilize the demand for health services by an aging population, thus stemming the tide of increasing costs and contributing to the future sustainability of the health care system.

5.5 LITERATURE CITED

1. Statistics Canada. *Population projections for Canada, Provinces and Territories*. Demography Division, ed. Ottawa, ON: Ministry of Industry, Government of Canada; 2010.

2. Canadian Institute for Health Information. *Health Care in Canada, 2011: A Focus on Seniors and Aging*. Ottawa, ON;2011.

3. Bloom DE, Canning D, Fink G. Implications of population aging for economic growth. In: *Program on the Global Demography of Aging: Working Paper Series*. Cambridge, MA: Harvard School of Public Health; 2011.

4. Gilmour H, Park J. Dependancy, chronic conditions and pain in seniors. *Health Reports.* 2006;16(Suppl):21-31.

5. Ramage-Morin PL, Shields M, Martel L. Health-promoting factors and good health among Canadians in mid- to late life. *Health Reports.* 2010;21(3):45-53.

6. Lankenau B, Solari A, Pratt M. International physical activity policy development: A commentary. *Public Health Reports.* 2004;119(3):352-355.

7. Vegda K, Nie J, Wang L, Tracy CS, Moineddin R, Upshur R. Trends in health services utilization, medication use, and health conditions among older adults: A 2-year retrospective chart review in a primary care practice. *BMC Health Services Research.* 2009;9(1):217.

8. Haapanen-Niemi N, Miilunpalo S, Vuori I, Pasanen M, Oja P. The impact of smoking, alcohol consumption, and physical activity on use of hospital services. *American Journal of Public Health.* 1999;89(5):691-698.

9. Janssen I. Health care costs of physical inactivity in Canadian adults. *Applied Physiology, Nutrition, and Metabolism.* 2012;37(4):803-806.

10. Janssen I, Shepard DS, Katzmarzyk PT, Roubenoff R. The healthcare costs of sarcopenia in the United States. *Journal of the American Geriatrics Society.* 2004;52(1):80-85.

11. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

12. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: An update. *Canadian Journal of Applied Physiology.* 2004;29(1):90-115.

13. Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

14. Sari N. A short walk a day shortens the hospital stay: Physical activity and the demand for hospital services for older adults. *Canadian Journal of Public Health.* 2010;101(5):385-389.

15. United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council of Physical Fitness and Sport. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Public Health Service, CDC, National Center for Chronic Disease Prevention and Health Promotion; 1996.

16. Chodzko-Zajko W, Schwingel A, Park CH. Successful aging: The role of physical activity. *American Journal of Lifestyle Medicine.* 2009;3:20-28.

17. Paterson DH, Jones GR, Rice CL. Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Canadian Journal of Public Health.* 2007;98 (Suppl 2):S69-S108.

18. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scandinavian Journal of Medicine & Science in Sports.* 2006;16(S1):3-63.

19. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: The evidence. *Canadian Medical Association Journal.* 2006;174(6):801-809.

20. Herman KM, Ardern CI, Mason C, Brien SE, Katzmarzyk PT. Trends in physical activity research in Canada. *Applied Physiology, Nutrition, and Metabolism.* 2007;32(3):400-408.

21. Davis JC, Marra CA, Robertson MC, Najafzadeh MA, Liu-Ambrose T. Sustained economic benefit of resistance training in community-dwelling senior women. *Journal of the American Geriatrics Society.* 2011;59:1232-1237.

22. Davis JC, Bryan S, Marra CA, Sharma D, Chan A, Beattie BL, Graf P, Liu-Ambrose T. An economic evaluation of resistance training and aerobic training versus balance and toning exercises in older adults with mild cognitive impairment. *PLoS ONE.* 2013;8(5):e63031.

23. Davis JC, Marra CA, Robertson MC, Khan KM, Najafzadeh MA, Ashe MC, Liu-Ambrose T. Economic evaluation of dose–response resistance training in older women: A cost-effectiveness and cost-utility analysis. *Osteoporos International.* 2011;22(5):1355-1366.

24. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, Wagner EH. The effect of strength and endurance training on gait, balance, fall risk and health services use in community-living older adults. *Journal of Gerontology.* 1997;52A(4):M218-M224.

25. Courtney M, Edwards H, Chang A, Parker A, Finlayson K, Hamilton K. Fewer emergency readmissions and better quality of life for older adults at risk of hospital readmission: A randomized controlled trial to determine the effectiveness of a 24-week exercise and telephone follow-up program. *Journal of the American Geriatrics Society.* 2009;57(3):395-402.

26. Ackermann RT, Williams B, Nguyen HQ, Berke EM, Maciejewski ML, LoGerfo JP. Healthcare cost differences with participation in a community-based group physical

activity benefit for Medicare managed care health plan members. *Journal of the American Geriatrics Society.* 2008;56:1459-1465.

27. Nguyen HQ, Ackermann RT, Maciejewski M, Berke EM, Patrick M, Williams B, LoGerfo JP. Managed-Medicare health club benefit and reduced health care costs among older adults. *Preventing Chronic Disease.* 2008;5(1):1-10.

28. Chen IJ, Chou CL, Yu S, Cheng SP. Health services utilization and cost utility analysis of a walking program for residential community elderly. *Nursing Economics.* 2008;26(4):263-269.

29. Reeder BA, Chad KE, Harrison EL, Ashworth NL, Sheppard MS, Fisher KL, Bruner BG, Quinn BG, Pahwa P, Hossain MA. Saskatoon *in motion*: Class- versus home-based exercise intervention for older adults with chronic health conditions. *Journal of Physical Activity & Health.* 2008;5(1):74-87.

30. Lindstrom B, Chad K, Ashworth N, et al. Effectiveness of recruitment strategies for a physical activity intervention in older adults. *Journal of Physical Activity & Health.* 2004;1(3):259-269.

31. Health Canada, Canadian Society for Exercise Physiology. *Canada's Physical Activity Guide for Older Adults*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1999.

32. King AC, Rejeski WJ, Buchner DM. Physical activity interventions targeting older adults: A critical review and recommendations. *American Journal of Preventive Medicine.* 1998;15:316-333.

33. Reeder BA, Chad KE, Harrison EL, et al. Saskatoon *in motion*: 12-month follow-up of a class- versus home-based exercise intervention for older adults with chronic health conditions. *Canadian Journal of Public Health (submitted);* 2013.

34. Ware JE, Kosinski M, Turner-Bowker DM, Gandek B. *How to Score Version 2 of the SF-12 Health Survey.* Lincoln, RI: QualityMetric Inc.; 2002.

35. Ware JEJ, Kosinski M, Keller SD. A 12-Item short-form health survey: Construction of scales and preliminary tests of reliability and validity. *Medical Care.* 1996;34(3):220-233.

36. Dinger MK, Oman F, Taylor EL, Vesely SK, Able J. Stability and convergent validity of the Physical Activity Scale for the Elderly (PASE). *Journal of Sports Medicine and Physical Fitness.* 2004;44(186-192).

37. New England Research Institutes. *PASE: Physical Activity Scale for the Elderly. Administration and Scoring manual*. Watertown, MA: New England Research Institutes, Inc.; 1991.

38. Schuit AJ, Schouten EG, Westerterp KR, Saris WHM. Validity of the Physical Activity Scale for the Elderly (PASE): According to energy expenditure assessed by the doubly labeled water method. *Journal of Clinical Epidemiology.* 1997;50(5):541-546.

39. Washburn RA. Assessment of physical activity in older adults. *Research Quarterly for Exercise and Sport.* 2000;71:S79-S88.

40. Washburn RA, McAuley E, Katula J, Mihalko SL, Boileau RA. The Physical Activity Scale for the Elderly (PASE): Evidence for validity. *Journal of Clinical Epidemiology.* 1999;52(7):643-651.

41. Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): Development and evaluation. *Journal of Clinical Epidemiology.* 1993;46(2):153-162.

42. Statistics Canada. *1998 National Population Health Survey*. Ottawa, ON: Health Statistics Division; 2001:12-15.

43. Saskatchewan Ministry of Health. *Health Services Databases: Information Document*. Epidemiology & Research Unit Population Health Branch, ed. Regina, SK: Saskatchewan Ministry of Health; 2010.

44. Dunlop S, Coyte PC, McIsaac W. Socio-economic status and the utilization of physicians' services: Results from the Canadian National Population Health Survey. *Social Science & Medicine.* 2000;51(2000):123-133.

45. McColl M, Shortt S. Another way to look at high service utilization: The contribution of disability. *Journal of Health Services Research & Policy.* 2006;11(2):74-80.

46. Bank of Canada. Rates & Statistics. 2013; (02 July). http://www.bankofcanada.ca/rates/related/inflation-calculator/.

47. Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the United States. *The Milbank Memorial Fund Quarterly.* 1973;51(1):95-124.

48. Andersen RM. Revisiting the behavioral model and access to medical care: Does it Matter? *Journal of Health and Social Behavior.* 1995;36(1):1-10.

49. King M, Judge J, Whipple R, Wolfson L. Reliability and responsiveness of two physical performance measures examined in context of a functional training intervention. *Physical Therapy.* 2000;80(1):8-16.

50. Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging & Physical Activity.* 1999;7:129-161.

51. Reuben D, Siu A. An objective measure of physical function of elderly outpatients: The Physical Performance Test. *Journal of the American Geriatrics Society.* 1990;38:1105-1112.

52. Verghese J, Wang C, Xue X, Holtzer R. Self-reported difficulty in climbing up or down stairs in non-disabled elderly. *Archives of Physical Medicine and Rehabilitation.* 2008;89(1):100-104.

53. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Nutrtition, Energy, and Human Performance.* 7th edition. Baltimore, MD: Lippincott Williams & Wilkins; 2009.

54. Samsa G, Edelman D, Rothman ML, Williams GR, Lipscomb J, Matchar D. Determining clinically important differences in health status measures: A general approach with illustration to the Health Utilities Index Mark II. *Pharmacoeconomics.* 1999;15(2):141-151.

55. Denkinger MD, Lukas A, Herbolsheimer F, Peter R, Nikolaus T. Physical activity and other health-related factors predict health care utilisation in older adults. *Zeitschrift für Gerontologie und Geriatrie.* 2012;45(4):290-297.

56. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika.* 1986;73(1):13-22.

57. Twisk JWR. *Applied Longitudinal Data Analysis for Epidemiology - A Practical Guide.* Cambridge: Cambridge University Press; 2003.

58. Hosmer DW, Lemeshow S. *Applied Logistic Regression.* New York: John Wiley & Sons, Inc; 2000.

59. Hedeker D, Gibbons RD. Application of random-effects pattern mixture models for missing data in longitudinal studies. *Psychological Methods.* 1997;2(64-78).

60. Kivitz A, Fairfax M, Sheldon EA, et al. Comparison of the effectiveness and tolerability of Lidocaine patch 5% versus Celecoxib for osteoarthritis-related knee pain: Post hoc analysis of a 12-week, prospective, randomized, active-controlled, open-label, parallel-group trial in adults. *Clinical Therapeutics* 2008;30(12):2366-2377.

61. Pauler DK, McCoy S, Moinpour C. Pattern mixture models for longitudinal quality of life studies in advance stage disease. *Statistics in Medicine.* 2003;22:795-809.

62. Reid R, Evans R, Barer M, Sheps S, Kerluke K, McGrail K, Hertzman C, Pagliccia N. Conspicuous consumption: Characterizing high users of physician services in one Canadian province. *Journal of Health Services Research & Policy.* 2003;8(4):215-224.

63. Luppa M, Sikorski C, Motzek T, Konnopta A, Konig H-H, Reidel-Heller SG. Health service utilization and costs of depressive symptoms in late life - A systematic review. *Current Pharmaceutical Design.* 2012;18(36):5936-5957.

64. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4):392-410.

65. Petrella RJ, Pedersen L, Cunningham DA, Koval JJ, Paterson DH. Physician contact with older community patients: Is there an association with physical fitness? *Preventive Medicine.* 1999;29(6):571.

66. Leon-Munoz LM, Guallar-Castillon P, Lopez Garcia E, Banegas JR, Gutierrez-Fisac JL, Rodriguez-Artalejo F. Relationship of BMI, waist circumference, and weight change with use of health services by older adults. *Obesity Research.* 2005;13(8):1398-1404.

67. Clark AL, Fonarow GC, Horwich TB. Waist circumference, body mass index, and survival in systolic heart failure: The obesity paradox revisited. *Journal of Cardiac Failure.* 2011;17(5):374-380.

68. Dorner TE, Reider A. Obesity paradox in elderly patients with cardiovascular diseases. *International Journal of Cardiology*. 2012;155(56-65).

69. Lang PO, Michel JP, Zekry D. Frailty syndrome: A transitional state in a dynamic process. *Gerontology.* 2009;55:539-549.

70. Warburton DER, Nicol CW, Bredin SSD. Prescribing exercise as preventive therapy. *Canadian Medical Association Journal.* 2006;174(7):961-974.

71. Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Medicine & Science in Sports & Exercise.* 2001;33(6 Suppl):S446-S451.

72. Rankinen T, Bouchard C. Genetic differences in the relationships among physical activity, fitness, and health. In: Bouchard C, Blair SN, Haskell WL, eds. *Physical Activity and Health*. 2nd ed: Human Kinetics, Inc; 2012:381-408.

73. Woolcott JC, Ashe MC, Millar WC, Shi P, Marra CA, PACC Research Team. Does physical activity reduce seniors' need for healthcare? A study of 24 281 Canadians. *British Journal of Sports Medicine.* 2010;44:902-904.

74. Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE, Kho ME, Hicks A, LeBlanc AG, Zehr L, Murumets K, Duggan M. New Canadian physical activity guidelines. *Applied Physiology, Nutrition & Metabolism.* 2011;36:36-46.

75. Svege I, Kolle E, Risberg M. Reliability and validity of the Physical Activity Scale for the Elderly (PASE) in patients with hip osteoarthritis. *BMC Musculoskeletal Disorders.* 2012;13(1):26.

76. Copeland JL, Esliger DW. Accelerometer assessment of physical activity in active, healthy older adults. *Journal of Aging & Physical Activity.* 2009;17(1):17-30.

CHAPTER SIX

GENERAL DISCUSSION AND CONCLUSIONS

There is growing interest among policymakers in the potential role of physical activity (PA) as a strategy to mitigate the challenges associated with an aging population, specifically the potential pressures on the health care system presented by an increasing need and demand for long term management of chronic health conditions.[1-3] The existing literature related to PA and health services utilization and costs falls into one of two streams: 1) observational studies that may or may not be population-based; and 2) clinical trials or retrospective cohort studies examining various exercise interventions.[4] However, few Canadian studies have examined associations between PA participation and health services utilization and/or costs, particularly as it pertains to older adults.[4] Furthermore, there is very limited Canadian data on the effects of PA interventions on subsequent health services utilization and health care costs in the older adult population.[4-7] The two studies included in this dissertation aimed to address these significant gaps in the literature by: 1) using population-based nationally representative survey data to examine the association between LTPA and the use of health services in community-dwelling older Canadians; and 2) exploring the potential impact of PA on the health care system by examining the longitudinal effects of a randomized community-based physical activity intervention on health services utilization and health care costs in a group of sedentary older adults with selected chronic health conditions. Taken together, the findings of these two studies provide novel insights into the relationship between physical activity and health services utilization, and in turn, health care costs among the older adult population in Canada.

6.1 SUMMARY OF MAJOR FINDINGS

The primary findings from Study 1 and Study 2 are presented in Table 6.1 and are briefly summarized below.

6.1.1 Study 1

In this study, it was hypothesized that there would be a negative association between LTPA and health service utilization, after adjusting for other predisposing, enabling and health need factors associated with health services utilization. The results showed that LTPA appeared to be associated with lower health services utilization; however, few of the associations were statistically significant. In the youngest age group, active older adults reported 8% fewer GP consultations annually than their inactive counterparts. Among older adults in the middle age group, LTPA was significantly associated with the use of hospital services. Active seniors between the ages of 65 and 79 were 18% less likely to be hospitalized and spent, on average, 7% fewer nights (NS) in hospital than their inactive counterparts. The differing associations between LTPA and health services utilization in the respective age groups may highlight changes in health care needs along an aging and/or chronic disease pathway. For example, many chronic conditions emerge and are diagnosed in 50 to 65 year age range, which may explain, at least partly, the stronger association between LTPA and physician visits in this age group compared to the others. Disease progression and age-related functional changes from ages 65-79 may significantly worsen overall health, thus explaining the stronger associations between LTPA and hospital services utilization in this age group.

Table 6.1 Summary of thesis findings

	Primary findings	
	Study 1	Study 2
# of annual visits to GP physician	• LTPA significantly associated with GP consults in youngest age group (50-64 yr.) only – Active (>3.0 KKD) were 27% less likely to contact a GP compared to inactive – Active had 8% fewer GP visits/yr. • Typical daily activity significantly associated with GP visits – Standing/walking associated with fewer GP consultations (80+ yrs.) – Lifting light/heavy loads negatively associated with GP contacts (65-79 yr.), number of GP consults (all age groups)	• Mean visits increased by 1 visit over the 5 year period (6.1 to 7.2 visits; BL to Yr. 4) (NS). – Significantly more visits in Yr. 2 and Yr. 3 compared to baseline. – No difference between CB and HB group in GP visits until Yr. 4 – when HB group had significantly more visits than CB group. • Annual GP visits positively associated with the number of chronic conditions (IRR_{adj}=1.11; p=.01) • No other covariates were significantly associated with annual GP visits; however self-reported physical health (PCS-12; *p*=0.062), CV endurance (*p*=.462) and lower body strength/endurance (CSST; *p*=.100) were retained in the final model.
Frequent use of GP physician services	• LTPA not significantly associated with frequent use of GP services – Direction of associations suggests that LTPA associated with decreased likelihood of frequent use of GP services • Typical daily activity significantly associated with frequent use of GP services – Standing/walking associated with decreased odds of being a frequent user of GP services (all age groups)	• The proportion of frequent users (≥10 visits/yr.) decreased by 5% (16% to 11%) between BL and Yr.1. • The proportion of frequent users was significantly higher than BL at Yr. 2 (24%; *p*<.01) and Yr. 3 (32%; *p*<.001) • Frequent use of GP services was positively associated with the number of chronic conditions (OR_{adj}=1.23; p<0.05) and level of education (OR_{adj}=3.1; p<0.05). No other covariates were significantly associated with frequent use of GP services; however self-reported physical health (PCS-12; *p*=0.059) and CV endurance (*p*=0.059) were retained in the final model.

Table 6.1 continued

	Primary findings	
	Study 1	Study 2
Annual Costs of GP Physician Services	Not Assessed	• Mean annual costs increased by less than $100 over the 5-yr study period. • No significant differences in GP costs between CB and HB groups; or over time. • Annual GP costs were negatively associated with income >$30,000 ($\beta$=-0.076; p<0.05) and positively associated with the number of GP visits (β=0.070; p<0.001) and CV endurance (β=0.000; p<0.05). No other covariates were significantly associated with annual GP costs; however number of chronic conditions (p=0.531), self-reported physical health (PCS-12; p=0.621), age (p=0.245) and functional fitness (p=0.284 and p=0.265; CSST and TSCT respectively) were retained in the final model.
Contact with specialist physician	• LTPA not significantly associated with contact with a specialist physician – Direction of association suggests that active respondents more likely to have contact with specialist (65-79 yr. and 80+ yr. age groups) • Typical daily activity significantly associated with specialist contacts – Standing/walking associated with 12% lower likelihood of specialist contact (65-79 yr.) – Lifting light/heavy loads associated 15% - 28% lower likelihood of specialist contact (50-64yr; 80+yr age groups)	• ~ 80% of participants saw a specialist at least once each year, including the baseline year • The odds of seeing a specialist did not differ significantly between the CB and HB groups and did not change over the study period • Contact with a specialist physician was positively associated with the number of GP visits (OR_{adj}=1.25; p<0.01) and the number of chronic conditions (OR_{adj}=1.834; p<0.001); and was negatively associated with performance on the CSST (OR_{adj}=0.869; p=0.001). No other covariates were significantly associated with annual GP costs; however self-reported physical health (PCS-12; p=0.735), income >$30,000 ($p$=0.213) were retained in the final model.

Table 6.1 continued

	Primary findings	
	Study 1	Study 2
# of annual visits to specialist physician	• LTPA not significantly associated with the number of specialist visits – Associations are generally positive, indicating LTPA is associated with more visits • Typical daily activity significantly associated with the number of specialist visits – Standing/walking and lifting light/heavy loads associated with 14-34% fewer visits (all age groups)	• Mean visits increased by approx. 1 visit over the 5 year period (3.3 to 4.0 visits; BL to Yr. 4) (NS). – More visits in Yr. 2 and Yr. 3 compared to baseline (4.5 visits/yr., both yrs.) – No difference between CB and HB group in number of visits – Significant group by time interaction in Yr. 3, indicating a greater rate of change in specialist visits in the HB group in this year. • Annual specialist visits positively associated with the # of GP visits (IRR_{adj}=1.10; *p*<.001), # of chronic conditions (IRR_{adj}=1.10; *p*=.01), age (IRR_{adj}=1.02; *p*<.05), gender (IRR_{adj}=1.57; *p*<.01) and CV endurance (IRR_{adj}=1.002; *p*<.05). Stronger performance on the CSST was associated with fewer specialist visits (IRR_{adj}=0.94; *p*<.01) and poorer performance of the TSCT was associated with a higher rate of specialist visits (IRR_{adj}=1.08; *p*<.05). No other covariates were retained in the final model.
Frequent use of specialist physician services	• LTPA not significantly associated with frequent use of specialist physician services in any age group. – The direction of the association was generally negative which suggests that LTPA may protect against being a frequent user of specialist services (except in the 80 yrs. & older group). • Typical daily activity significantly negatively associated with frequent use of specialist services in all age groups. – Standing/walking and lifting light/heavy loads associated with 17-42% lower odds of being a frequent user of specialist services	• The odds of being a frequent user (>6visits/yr.) was approximately 41% higher at Yr. 4 compared to BL (*p*<.05) • In Yr. 4, HB participants were significantly less likely than CB participants to be frequent users (OR_{adj}=0.100; p<0.05) • Frequent use was negatively associated with income >$30,000 ($OR_{adj}$=0.344; *p*<0.01) and positively associated with the number of GP visits (OR_{adj}=1.17; *p*<0.001) chronic conditions (OR_{adj}=1.53; *p*=0.01) and post-secondary education (OR_{adj}=3.20; *p*=0.05). • Frequent use was negatively associated with waist circumference (OR_{adj}=0.955; *p*<0.05) and positively associated with BMI (OR_{adj}=1.17; *p*<0.05). • No other covariates were significantly associated with frequent use; however self-reported age (*p*=0.194) physical health (PCS-12; *p*=0.932), CV endurance (*p*=0.362), PA (*p*=0.989) functional fitness (*p*=0.354 and *p*=0.112; CSST and TSCT respectively) were retained in the final model.

Table 6.1 continued

	Primary findings	
	Study 1	Study 2
Specialist Physician Costs	Not Assessed	• Mean annual specialist costs increased by approximately $125 over the 5-yr study period. • No significant differences in specialist costs between CB and HB groups; or over time. • Annual specialist costs were positively associated with the number of GP visits (β=0.052; p=0.001), number of specialist visits (β=0.050; p<0.05) and the number of chronic conditions (β=0.131; p<0.001) and negatively associated with post-secondary education (β= -0.319; p<0.05). Stronger performance on the CSST test was associated with lower specialist costs (β= -0.051; p<0.001). No other covariates were significantly associated with annual specialist costs; however self-reported physical health (PCS-12; p=0.675), income (p=0.139) and performance on the TSCT (p=0.232) were retained in the final model.
Hospital admissions	• Active 65-79 yr. olds were 18% less likely to be hospitalized overnight compared to inactive • Typical daily activity significantly associated hospital admissions – Lifting light/heavy loads associated with 32% lower likelihood of being hospitalized overnight (65-79 yr.)	• 81 of 128 (63.3%) participants were admitted to hospital at least once during the 5-yr study period – 28.9% had at least one overnight hospitalization – 56.3% had at least one day surgery admission • Hospital admissions increased from 13.5% to 27% between baseline and Yr. 3. In Yr. 4 the proportion admitted to hospital decreased to 21% (NS) • Odds of being admitted to hospital were not significantly different between CB and HB groups; or over time. • Hospital admissions were negatively associated with the number of GP visits increased (OR_{adj}=0.895; p<0.05), self-reported physical health (PCS-12; OR_{adj}=0.960, p<0.05) and positively associated with post-secondary education (OR_{adj}=2.45; p<0.01). • No other covariates were significantly associated with being admitted to hospital; however, number of specialist visits (p=0.332), number of chronic conditions (p=0.290), physical activity (p=0.104), sedentary behaviour (p=0.201), and performance on the TSCT (p=0.191) were retained in the final model.

Table 6.1 continued

	Primary findings	
	Study 1	Study 2
Nights in hospital	• LTPA not significantly associated with the number of nights spent in hospital • Typical daily activity significantly associated with the number of specialist visits – Standing/walking associated with 22% fewer nights in hospital (50-64 yr.) – Lifting light/heavy loads associated with 42-46% fewer nights in hospital (65-79 yr.; 80+ yr.)	• Mean nights in hospital increased each study year, going from 1.8 nights in Yr. 1, to a peak of 10.8 nights in Yr. 3. In Yr. 4, the average nights in hospital returned to the same level as baseline (1.7 nights). • No further statistical analyses were done, given the low frequency of overnight hospitalizations during the study period.
Hospital costs	Not Assessed	• Mean annual total costs grew by ~500% between baseline and Yr. 3, going from an average of $193 to almost $1200 before dropping by approximately 40% (to $684) in Yr. 4 (NS). • Hospital costs did not differ significantly between CB and HB groups • Hospital costs were positively associated with the number of GP visits (β=0.066, p<.001) and self-reported physical health (β=0.014, p<.05) and negatively associated with post-secondary education (β= -0.345, p<.05). • Sedentary behaviour was positively associated with higher hospital costs (β=0.013, p=.01), as was poorer performance of Timed Stair Climb Test (β=0.083, p<.05). No other covariates were significantly associated with hospital costs; however number of specialist visits (p=.064), the number of chronic conditions (p=.129), income (p=.306), level of physical activity (p=.074), and blood pressure (MAP; p=.068) were retained in the final model.

In both instances, LTPA appears to play an important role, possibly by delaying the clinical manifestation of certain conditions or slowing progression of the disease process, thereby helping to delay or prevent health services utilization in active older adults. This has been described as the "compression of morbidity" – a hypothesis first put forth by Dr. James Fries in 1980 and now a cornerstone of healthy aging. This paradigm presupposes that by delaying the age of onset of chronic infirmity, morbidity will be compressed into a shorter period of time.[8,9] The compression of morbidity has a positive impact on physical function, thereby slowing the rate of decline in functional capacity and delaying the onset of disability and frailty, as is illustrated in Figure 2.1 Assuming that life expectancy remains relatively stable, the end result would then be expected to be the maintenance of independence and quality of life for a longer period of time and a reduction in the overall burden of illness.[8-10] Although the associations between LTPA measures of health services utilization were not statistically significant among those 80 years of age and older, the direction of the associations offers some support for the hypothesis that LTPA may be associated with lower health services utilization in this age group as well.

While LTPA was the primary focus of Study 1, typical daily activity outside of that undertaken for leisure or transportation emerged as a stronger predictor of all types of health services utilization, particularly in the two oldest age groups. Even in the youngest age group, typical daily activity was significantly associated with the use of specialist services, where LTPA was not. It is possible that this variable provides an indication of sedentary behaviour, which is associated with the development and chronic health conditions and poorer health status, independent of LTPA.[11] Among younger older adults still in the workforce, the accrual of PA during a typical day depends largely on their occupation and may or may not exceed that accrued through LTPA. Therefore, typical daily activity may be a more salient predictor of health services utilization than LTPA in this population. Among retired older adults, particularly those in the oldest age group, typical daily PA may reflect greater mobility, physical function and health status and thus, may be a stronger predictor of health services utilization than LTPA in those aged 80 years and older. Recently, Santos et al, (2012) and Gennuso et al (2013) reported that sedentary behaviour was positively associated with physical function and functional fitness among inactive and active older adults alike.[12,13] Thus, reducing time spent in sedentary activities may be as important as increasing LTPA in minimizing the age-related declines in functional capacity that precede the loss of independence and increase the risk of frailty in older adults (see Figure 2.1).[12,13]

6.1.2 Study 2

Study 2 examined the effects of a randomized community-based PA intervention (50+ *in motion*) on health services utilization and health care costs over a 4-year follow-up period in a group of sedentary older adults with selected chronic health conditions. This study compared physician and hospital services utilization and costs between two types of physical activity programs – a supervised class-based program and an unsupervised home-based program. The results suggest that CB and HB physical activity interventions are equally effective in preventing increases in health services utilization and health care costs over the long term in community dwelling older adults.

Study 2 also examined the longitudinal effects of physical activity, cardiorespiratory endurance, body composition and functional fitness on the use of physician and hospital services and costs by participants in the 50+ *in motion* intervention. It was hypothesized that after adjusting for potential confounders, higher levels of physical activity, better cardiorespiratory endurance, greater functional fitness and more optimal body composition would be associated with lower health services utilization and costs. This hypothesis was only partially supported. Hospital admissions and health care costs associated with both physician and hospital services utilization did not significantly change between baseline and the end of the follow-up period. After an initial decrease in the first year after the intervention, rates of GP and specialist services utilization increased throughout the follow-up period, peaking in Yr.3, before dropping to a level that was not significantly different than baseline in the final follow-up year. Frequent use of specialist visits remained at baseline levels through the study period until the final follow-up year, when they were significantly higher. While the intervention did not result in lowered health services utilization and costs, the results suggest that both the CB and HB arms of the 50+ *in motion* intervention may have been effective at preventing increases in hospital services utilization and overall health care costs over a 5-year period in a group of community dwelling older adults with chronic disease. In Canada, the greatest proportion of public-sector health care spending (37.3%) is directed towards hospitals /hospital services, with another important driver of public spending on health care being the increasing use of physician services, and in particular, medical specialists.[14] Therefore, these results suggest that PA interventions such as the 50+ *in motion* intervention may be an effective cost-containment strategy that could, over the long term, have a positive impact in terms of health care sustainability.

Measures of functional fitness emphasizing lower body strength, endurance and power were more consistently associated with lower health services utilization than CV endurance, body composition or physical activity. Functional limitations are strongly associated with the loss of independence, reduced quality of life, and the onset of frailty, all of which are likely to lead to increased use of physician services and increased risk of short and/or long-term hospitalization.[13] Thus, the findings in Study 2 highlight the importance of emphasizing physical activities that will build and/or maintain muscular strength, endurance, and power in public health messaging around PA and PA interventions for the older adult population.

Physical activity, fitness and sedentary behaviour have all been shown to be independently associated with health, so it was hypothesized that we would see independent associations between these three factors and various health services utilization variables. In Study 2, PA was not independently associated with any health services utilization or cost outcomes; however, sedentary time was associated with higher hospital costs, independent of physical activity, functional fitness, and health status. Although both PA and sedentary time were measured via self-report, accurate recall of PA using the PASE depends upon the respondent's ability to distinguish between different types and intensities of PA, as well as the accurate recall of time spent in these activities. On the other hand, recall of sedentary behaviour using the PASE is much more straightforward, requiring respondents to only recall the average time spent per day in sedentary pursuits, likely leading to a lesser degree of misclassification compared to PA. Given that fitness was measured objectively, and therefore, even less likely to result in misclassification, it follows that the results showed stronger and more consistent associations between functional fitness and health services utilization and costs, followed by those for sedentary behaviour, compared to associations between PA and health services utilization and costs.[15,16]

6.2 SUMMATIVE DISCUSSION

In the public health and health promotion literature, social ecological models are used to describe the interaction and interdependency between determinants of behaviour at multiple levels including intrapersonal (biological and psychological), interpersonal/cultural, institutional (companies, schools, health agencies), physical environment (built, natural) and policy (rules, regulations, laws).[17,18] This type of integrative framework is particularly suited as a foundation for interventions to achieve sustained changes in physical activity behaviour at the population level.[17] While not originally framed as a social ecological model, the Behavioral Model of Health Service Use (BMHSU) captures the essence of this approach. This framework presupposes that the use of health services within the context of particular health system and political, economic, geographic and cultural environment, is influenced by a range of predisposing, enabling and need-related population characteristics.[19,20] The BMHSU complements the current population health approach to public health that holds that good health and healthy aging are determined by more than simply an absence of illness but also by a number of non-medical factors including income and social status, education, employment, early childhood development, access to health services, and gender, cultural, and environmental issues (see Figure 2.2). Thus, the BMHSU was well suited as a conceptual framework to guide variable selection, particularly in Study 1.

Given that the need for care is the most salient determinant of health services utilization, it was not surprising that need related variables were most strongly associated with health services utilization and health care costs. While aging is associated with greater interaction with and dependency on the health care system in general, the Canadian Institutes for Health Information (CIHI) suggest that the amount of health services used by older adults is largely driven by the number of chronic conditions they have rather than their age; a statement supported by the strong associations between comorbidity and health services utilization and costs reported in Study 2.[21] Approximately 25% of seniors report having three or more chronic conditions; however this group accounts for 40% of reported health services utilization.[21] Furthermore, high comorbidity is associated with poorer self-rated health and quality of life. Roughly 50% of seniors reporting three or more chronic conditions rate their health as excellent, very good or good while more than three-quarters of seniors with fewer than three conditions rate their health the same way.[21] In comparison, close to 90% of participants in the 50+ *in motion* study rated their health as excellent, very good or good, with no difference between those reporting a single chronic condition versus those reporting more than 3 chronic conditions, despite increasing levels of health services utilization and health care costs with increasing levels of comorbidity.

The most recent estimates of the burden of physical inactivity in Canada indicate that the three most expensive chronic diseases attributable to physical inactivity are coronary artery disease ($2.7 billion), T2D ($1.4 billion), and stroke ($1.1 billion), followed by hypertension ($748 million), breast and colon cancer ($564 million), and osteoporosis ($241 million).[22] While the influence of comorbidity was not explicitly examined in Study 1, all participants in Study 2 had at least one of four CVD risk factors or other chronic conditions, including: hypertension, T2D, overweight/obesity, hyperlipidemia and osteoarthritis. Although the 50+ *in motion* intervention did not lead to an overall reduction in health services utilization or health care costs, that baseline levels of utilization and costs were maintained over a 5-year period is a promising finding. Given that the most costly chronic conditions associated with physical inactivity are related to CVD, efforts to reduce sedentary time and increase physical activity could be expected to have the largest impact on these conditions and thus, should be a focus of PA interventions for middle aged and older adults. However, the results of Study 2 also highlight the important role of functional strength and endurance, thus older adults should be encouraged to partake in a balanced program of physical activity that will enhance both cardiovascular and musculoskeletal fitness. Considering the physiological benefits of PA are so broad, there will likely be positive impacts in terms of reducing the burden of other conditions even while focusing primarily on the prevention of conditions with cardiovascular implications.

This study is one of the first Canadian studies to examine the longitudinal effects of physical activity, functional fitness and sedentary behaviour on health services utilization and health care costs. Although it is difficult to draw firm conclusions based on the results of this study, it adds to our understanding of these relationships in the Canadian context and highlights areas where further research is warranted. In particular, the findings of this study highlight the importance of functional fitness and to a lesser extent, sedentary behaviour, as a means to contain health services utilization and health care costs.

6.2.1 Strengths and Limitations

Prior research in the area of PA and health services utilization has predominantly been focused on adults in the workplace. This thesis is among a handful of studies to examine the relationship between PA and health services utilization in community dwelling older Canadians. Along with commonly assessed outcomes of health services utilization, both studies consider additional outcomes which speak to patterns of utilization that may also be of interest to health services policymakers. Furthermore, the use of negative binomial models in the analysis of count-based health services utilization variables increases the robustness of the estimates produced. Lastly, both studies endeavored to account for unobserved differences by including a comprehensive set of control variables; however due to its smaller sample size, purposeful selection of control variables was undertaken in order to account for the most important control variables while maintaining an appropriately parsimonious model.

The strengths of this thesis notwithstanding, the two studies have certain collective and specific limitations that should be considered when interpreting the results. Although it was not the primary purpose of this thesis to draw comparisons between the two study populations, the representative, population-based sample in Study 1 did provide a reference group for Study 2, particularly in regards to physician services utilization and hospital admissions. However, as is the case with much of the previous literature, it is very difficult to draw direct comparisons between the results of the two studies, primarily due to methodological differences and operationalization of the physical activity and sedentary behaviour variables. In Study 1, PA was measured using a categorical index derived from an indirect assessment of average daily energy expenditure in LTPA. In Study 2, PA was operationalized as a more global measure, taking into account activity associated with leisure time, ADLs, caregiving and work/volunteering. Likewise, typical daily activity is used as a proxy measure for sedentary behaviour in Study 1; however, in Study 2, sedentary activity is measured as a separate construct. Thus, it should be acknowledged that the studies in this thesis measure related but distinct aspects of physical activity and sedentary behaviour. A second limitation of this thesis is that both studies relied on self-reported measures of PA and sedentary behaviour, thus opening up the possibility of bias due to inaccurate recall or social desirability. Furthermore, there are issues with the use of self-report measures of PA in an older population including vision and hearing impairments or disturbances to cognition and short- or long-term memory.[23] Additional problems may include the ability to accurately report activity intensity, because perceptions of what is “hard” activity or “light” activity depend on the tolerance and fitness level of the individual, both of which decline as a person ages.[23] Additionally, only direct costs associated with health services utilization were assessed in either study. Indirect costs related to illness, disability, and/or premature death represent an equally substantial economic and social burden; thus, a substantial portion of costs associated with physical inactivity were not considered in this thesis. Lastly, neither Study 1 nor

Study 2 considered the use of commonly accessed non-public health services such as physical therapy and chiropractic medicine both of which are widely reported to be used in conjunction with standard medical care.[24] Likewise, complementary and alternative medicine (CAM) practices such as massage therapy, naturopathy and acupuncture were not considered in either study. Rates of CAM use vary widely in the literature but recently published nationally representative data suggest that approximately 12.5% of Canadians report visiting a CAM practitioner, with rates of use highest among those aged 25-64 compared to those over the age of 65 (19% vs. 11%, respectively).[24] That being said, this thesis does address the two most important drivers of public spending on health care – the use of physician services, along with the use of hospitals and hospital services.[14] The strengths and limitations specific to each study are outlined below.

Study 1

This study is among a select few population-based studies to examine the relationship between PA and health services utilization in a representative sample of community dwelling older Canadians. The majority of earlier studies are lacking in their ability to account for other factors associated with health services utilization, be it demographic and socio-economic factors, physical and mental health status and medical co-morbidities, or health behaviors such as smoking and drinking.[25-27] Study 1 included of a comprehensive set of health-related control variables which helped to account for variations in health that may affect both the level of physical activity and healthcare utilization.[25-27] Stratifying the data into three age groups coinciding with key transition periods and adjusting for age within each age group also allowed for a more precise examination of the association between PA and health services utilization in this diverse population. Furthermore, consideration of both LTPA and typical daily activity outside of that undertaken for leisure or transportation is unique and provides new insights into the relationship between PA and health services utilization in the older adult population.

The following limitations of Study 1 should guide the interpretation of results from this study. The cross sectional nature of Study 1 precludes the inference of causal relationships and one cannot discount the possibility that reverse causality between the outcome measures and one or more independent variables is present. Furthermore, given the self-reported nature of the data, bias due to inaccurate recall or social desirability remains a possibility, particularly in the PA and health services data. Previous studies have shown that older adults tend to over-report contacts with GP physicians and under-report contacts with medical specialists while recall of events such as hospitalizations appears to be more accurate, perhaps because these events are more highly salient and easily remembered.[28,29] A further limitation of Study 1 relates to the CCHS questionnaire itself. Discrepancies in the recall periods for the health services utilization (12-months) and LTPA (3-months) variables may have made it more difficult to identify significant relationships; however, it would be considerably more difficult to accurately recall PA behaviors over a 12 month period compared to a lower frequency event such as health services utilization over the same period.[25] Furthermore, the measurement of LTPA in the CCHS may underestimate older adults' LTPA, particularly in the oldest age group, for at least two reasons: 1) the instrument does not specifically include more prevalent leisure time activities of older adults, such as housekeeping or caregiving and 2) the questionnaire may not be sensitive enough to detect the typically light and brief activity of elderly people.[4,23]

Study 2

There are several limitations that should inform the interpretation of the results from Study 2. First, ethical considerations precluded the possibility of including a wait-list control group in the study design thereby limiting the conclusions that can be drawn about the effectiveness of the intervention. In order to address this in some way, we compared annual rates of physician services utilization and incidence of inpatient hospital admissions between participants in Study 2 and those reported by the representative population-based sample in Study 1. This showed that the intervention population in Study 2 generally had higher rates of physician visits and inpatient hospitalizations than that reported in the general population. While this does not allow use to make further conclusions about the effectiveness of the 50+ *in motion* intervention study, it does confirm that findings from Study 2 are limited in their generalizability to the larger older adult population.

Secondly, health care costs were determined based on health service utilization encounters which were captured in the Saskatchewan Health database. While the costs examined account for two major areas of publicly-funded health care expenditures (physician and hospital services), they represent only a subset of total health care expenditures since costs associated with prescription drugs (and a portion of medical laboratory and diagnostic imaging tests) were not included in this study. Furthermore, costs associated with the use of non-public health services, including CAM, were not considered. Thus, despite the high quality of the cost data in this study, a substantial proportion of total healthcare costs potentially remain unaccounted for.

The above limitations notwithstanding, Study 2 had several notable strengths. As one of a very few prospective, longitudinal studies of the effects of a PA intervention on health services utilization and health care costs in an older Canadian population, Study 2 makes an important contribution to the existing literature. Furthermore, the follow-up period considered in this study extends two years, at least, beyond that of other published data, allowing for a more detailed examination of longer-term effects of a PA intervention on health services utilization and costs.

The use of comprehensive administrative health data as the source of the health services utilization and costs data reduces the possibility of recall bias in the dependent variables. Lastly, the use of GEE methods and negative binomial models in the statistical approach instill confidence in the robustness of the estimates and the use of pattern mixture modeling to adjust for possible differences in the intervention among those lost-to-follow-up further strengthen the statistical rigor of this study.

6.2.2 *Future Research*

Future research in this area should continue to explore the relationships between PA and sedentary behavior, physical fitness and health services utilization and costs using observational and intervention-based approaches, focusing on the older adult population. Efforts are needed to identify a consistent set of 'gold standard' indicators of health services utilization and health care costs in order to facilitate comparisons across studies. While aging is associated with greater interaction with and dependency on the health care system in general, typically it is a very small proportion of the population that uses the vast majority of services.[21] Therefore, measures of intensity of use (e.g. comparing frequent/high users vs. typical users) or those related to more costly health services (i.e. specialist physician and hospital services utilization and costs) may have more policy-relevance, from a cost containment perspective. If a general consensus as to the most important and most relevant indicators of health services utilization and costs can be established, it will be much easier interpret findings and draw clearer conclusions based on a more cohesive understanding of the overall evidence-base.

Future research should also consider non-public health services utilization, including that associated with CAM, given that its use is becoming increasingly widespread and is likely to continue to grow, particularly among older adults, as the population ages. This would ensure more accurate estimates of the burden of physical inactivity and sedentary behaviour on health services utilization and health care costs. Likewise, the wider use of objective measures of PA and sedentary behaviour as well as direct measures of CV fitness would also serve to increase the robustness of estimates and, very likely, result in greater consistency in findings between studies, allowing researchers and policymakers to draw clearer conclusions from the evidence.

Prospective longitudinal studies with longer follow-up periods are needed in order to increase our understanding of the long term consequences of PA for health services utilization and costs. As outlined in Chapter 2, many questions remain as to the minimum and/or optimal dose of PA needed for health benefits; consequently there is also further work needed to be able to determine what dose of PA would be effective at reducing health services utilization and costs. Early projections by Katzmarzyk et al (2000) suggested that a 10% reduction in physical inactivity at a population level could reduce direct health care expenditures by $150 million/year while Sari (2010) estimated that a daily 20-minute walk would reduce total annual inpatient days by approximately 2 percent.[27,30] Nevertheless, further research is needed in order to determine conclusively the optimal dose of PA needed to impact health services utilization and costs. Lastly, the inclusion of variables related to sedentary behavior and measures of CV and functional fitness would add significantly to our understanding of the interplay between PA, physical fitness/functional capacity and the use of health services among older adults and allow policymakers to prioritize and develop more effective population-based health promotion strategies that foster healthy aging and improved quality of life for older Canadians.

6.3 CONCLUSION

In conclusion, the research findings presented in this thesis enhance our understanding of the relationships between physical activity, health services utilization and health care costs in older Canadians. This comprehensive scope of this thesis and the results thereof add to a growing body of evidence supporting the assertion that increasing physical activity participation has a critical role to play in reducing or maintaining health services utilization and health care costs in community dwelling older Canadians; however, the findings suggest that this relationship may not be as straightforward as suggested by earlier research. Older adults are a very diverse group and as this segment of population grows in numbers, a greater understanding of the heterogeneities in health services utilization in this population will become all the more important. While further research is needed to improve our understanding of the relationships between physical activity and sedentary behaviour, physical fitness, and health services utilization, the findings presented in this thesis suggest reducing sedentary behaviour and improving functional fitness in older adults may be as important as physical activity, if not more so, in terms of potential impact on health services utilization and health care costs. From an individual or patient perspective, the take home message is simply this: Sit less, move more, and do things to challenge your muscles on a daily basis. For health care professionals, the findings highlight the advantage that a team approach would bring to helping older adults to increase their physical activity in a way that is safe but that promotes the development of functional fitness. For health administrators, the findings suggest that the development of public health initiatives and interventions focused on functional fitness would likely have many benefits, not the least of which may be to stabilize the demand for health services by an aging population.

6.4 LITERATURE CITED

1. Lankenau B, Solari A, Pratt M. International physical activity policy development: A commentary. *Public Health Reports.* 2004;119(3):352-355.

2. Craig CL. Evolution and devolution of national physical activity policy in Canada. *Journal of Physical Activity and Health.* 2011;8:1044-1056.

3. Kohl HW, 3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, Kahlmeier S. Physical Activity 5: The pandemic of physical inactivity: global action for public health. *The Lancet.* 2012;380(9838):294-305.

4. Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

5. Davis JC, Marra CA, Robertson MC, Najafzadeh MA, Liu-Ambrose T. Sustained economic benefit of resistance training in community-dwelling senior women. *Journal of the American Geriatrics Society.* 2011;59:1232-1237.

6. Davis JC, Bryan S, Marra CA, Sharma D, Chan A, Beattie BL, Graf P, Liu-Ambrose T. An economic evaluation of resistance training and aerobic training versus balance and toning exercises in older adults with mild cognitive impairment. *PLoS ONE.* 2013;8(5):e63031.

7. Davis JC, Marra CA, Robertson MC, Khan KM, Najafzadeh MA, Ashe MC, Liu-Ambrose T. Economic evaluation of dose–response resistance training in older women: a cost-effectiveness and cost-utility analysis. *Osteoporos International.* 2011;22(5):1355-1366.

8. Fries JF. Aging, natural death, and the compression of morbidity. *New England Journal of Medicine.* 1980;303:130-135.

9. Chief Public Health Officer. *Report on the State of Public Health in Canada, 2010: Growing older - adding life to years*. Ottawa, ON: Government of Canada; 2010.

10. World Health Organization. *A Life Course Approach to Health*. Geneva: World Health Organization; 2000.

11. Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE, Kho ME, Hicks A, LeBlanc AG, Zehr L, Murumets K, Duggan M. New Canadian physical activity guidelines. *Applied Physiology, Nutrition & Metabolism.* 2011;36:36-46.

12. Gennuso KP, Gangnon RE, Matthews CE, Thraen-Borowski KM, Colbert LH. Sedentary behavior, physical activity and markers of health in older adults. *Medicine & Science in Sports & Exercise.* 2013;45(8):1493-1500.

13. Santos DA, Silva AM, Baptista F, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Experimental Gerontology.* 2012;47:908-912.

14. Canadian Institute for Health Information. *Health Care in Canada, 2011: A Focus on Seniors and Aging*. Ottawa, ON;2011.

15. Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitnesss more important in defining health benefits? *Medicine & Science in Sports & Exercise.* 2001;33(6 Suppl.):S379-S399.

16. Willis BL, Gao A, Leonard D, DeFina LF, Berry JD. Midlife fitness and the development of chronic conditions in later life. *Archives of Internal Medicine.* 2012;172(17):1333-1340.

17. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. *Annual Review of Public Health.* 2006;27:297-322.

18. Haggis C, Sims-Gould J, Winters M, Gutteridge K, McKay H. Sustained impact of community-based physical activity interventions: key elements for success. *BMC Public Health.* 2013;13(1):892.

19. Andersen RM, Newman JF. Societal and individual determinants of medical care utilization in the United States. *The Milbank Memorial Fund Quarterly.* 1973;51(1):95.

20. Andersen RM. Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior.* 1995;36(1):1-10.

21. Canadian Institute for Health Information. *Seniors and the Health Care System: What is the Impact of Multiple Chronic Conditions?* Ottawa, ON;2011.

22. Janssen I. Health care costs of physical inactivity in Canadian adults. *Applied Physiology, Nutrition, and Metabolism.* 2012;37(4):803-806.

23. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine.* 2003;37(3):197-206.

24. Metcalfe A, Williams J, McChesney J, Patten SB, Jette N. Use of complementary and alternative medicine by those with a chronic disease and the general population - Results of a national population based survey. *BMC Complementary & Alternative Medicine.* 2010;10:58.

25. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4):392-410.

26. Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

27. Sari N. A short walk a day shortens the hospital stay: Physical activity and the demand for hospital services for older adults. *Canadian Journal of Public Health.* 2010;101(5):385-389.

28. Raina PS, Kirkland SA, Wolfson C, et al. Accessing health care utilization fatabases for health tesearch: A Canadian longitudinal study on aging feasibility study. *Canadian Journal on Aging.* 2009;28(Special Issue 03):287-294.

29. Roos LL, Brownell M, Lix L, Roos NP, Walld R, MacWilliam L. From health to research: Privacy, methods, approaches. *Social Science & Medicine.* 2008;66:117-129.

30. Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

BIBLIOGRAPHY

Afilalo J, Marinovich A, Afilalo M, Colacone A, Léger R, Unger B, Giguère C. Nonurgent emergency department patient characteristics and barriers to primary care. *Academic Emergency Medicine.* 2004;11(12):1302-1310.

Ackermann RT, Cheadle A, Sandhu N, Madsen L, Wagner EH, LoGerfo JP. Community exercise program use and changes in healthcare costs for older adults. *American Journal of Preventive Medicine.* 2003;25(3):232-237.

Ackermann RT, Williams B, Nguyen HQ, Berke EM, Maciejewski ML, LoGerfo JP. Healthcare cost differences with participation in a community-based group physical activity benefit for Medicare managed care health plan members. *Journal of the American Geriatrics Society.* 2008;56:1459-1465.

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of physical activities: A second update of codes and MET values. *Medicine & Science in Sports & Exercise.* 2011;43(8):1575-1581.

Allen J, Morelli V. Aging and exercise. *Clinics in Geriatric Medicine.* 2011;27:661-671.

Almeida M. Aging mechanisms in bone. *Bonekey Reports.* 2012;1(1).

Anderson AS, Loeser RF. Why is osteoarthritis and age-related disease? *Best Practice & Research Clinical Rheumatology.* 2010;24:15-26.

Anderson LH, Martinson BC, Crain AL, Pronk NP, Whitebird RR, O'Connor PJ, Fine LJ. Health care charges associated with physical inactivity, overweight, and obesity. *Preventing Chronic Disease.* 2005;2(4):A09.

Andersen RM. Behavioral model of families' use of health services. *Research Series No. 25*. Chicago, IL: Health Administration Studies, University of Chicago; 1968.

Andersen RM. Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior.* 1995;36(1):1-10.

Andersen RM, Newman JF. Societal and individual determinants of medical care in the United States. *Milbank Memorial Fund Quarterly Journal.* 1973;51:95-124.

Andreyeva T, Sturm R. Physical activity and changes in health care costs in late middle age. *Journal of Physical Activity and Health.* 2006;3:S6-S19.

Asada Y, Kephart G. Equity in health services use and intensity of use in Canada. *BMC Health Services Research.* 2007;7(1):41.

Ashworth NL, Chad KE, Harrison EL, Reeder BA, Marshall SC. Home versus center-based physcial activity programs in older adults. *Cochrane Database of Systematic Reviews.* 2005 (Updated 2009);Issue 1.

Babitsch B, Gohl D, von Lengerke T. Re-revisiting Andersen's behavioral model of health services use: A systematic review of studies from 1998-2011. *GMS Psychosocial Medicine.* 2012;9(Doc 11):1-15.

Balducci L, Ershler WB. Cancer and ageing: A nexus at several levels. *Nature Reviews Cancer.* 2005;5(8):655-662.

Bank of Canada. Rates & Statistics. 2013; (02 July). http://www.bankofcanada.ca/rates/related/inflation-calculator/.

Baron JA, Weiderpass E. An introduction to epidemiological research with medical databases. *Annals of Epidemiology.* 5// 2000;10(4):200-204.

Barron AM, Pike CJ. Sex hormones, aging and Alzheimer's disease. *Frontiers in Bioscience (Elite Edition).* 2013;4:976-997.

Barzilai N, Gabriely I. Genetic studies reveal the role of the endocrine and metabolic systems in aging. *Journal of Clinical Endocrinology and Metabolism.* 2010;95(10):4493-4500.

Barzilai N, Huffman DM, Muzumdar RH, Bartke A. The critical role of metabolic pathways in aging. *Diabetes.* 2012;61(6):1315-1322.

Barzilay JI, Stein PK. Association of the metabolic syndrome with age-related, nonatherosclerotic, chronic medical conditions. *Metabolic Syndrome and Related Disorders.* 2011;9(5):327.

Beland Y. Canadian Community Health Survey - Methodological overview. *Health Reports.* 2002;13(3):9-14.

Berger MJ, Doherty TJ. Sarcopenia: Prevalence, mechanisms, and functional consequences. In: Mobbs CV, Hof PR, eds. *Body Composition and Aging*. New York: Karger; 2010.

Bernatsky S, Lix L, O'Donnell S, LaCaille D, Network C. Consensus statements for the use of administrative health data in rheumatic disease research and surveillance. *The Journal of Rheumatology*. January 1, 2013 2013;40(1):66-73.

Birnbaum HG, Cremieux PY, Greenberg PE, LeLorier J, Ostrander JA, Venditti L. Using healthcare claims data for outcomes research and pharmacoeconomic analyses. *Pharmacoeconomics.* 1999;16(1):1-8.

Blackwell DL, Martinez ME, Gentleman JF, Sanmartin C, Berthelot JM. Socioeconomic status and utilization of health care services in Canada and the United States: Findings from a binational health survey. *Medical Care* 2009;47(11):1136-1146.

Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitnesss more important in defining health benefits? *Medicine & Science in Sports & Exercise.* 2001;33(6 Suppl.):S379-S399.

Bloom DE, Canning D, Fink G. Implications of population aging for economic growth. In: *Program on the Global Demography of Aging: Working Paper Series*. Cambridge, MA: Harvard School of Public Health; 2011.

Bombardier C, Hawker G, Mosher D. *The Impact of Arthritis in Canada: Today and over the next 30 years.* Toronto, ON: Arthritis Alliance of Canada; 2011.

Borzecki AM, Lee A, Kalman D, Kazis LE. Do poor health behaviors affect health-related quality of life and healthcare utilization among veterans? *Journal of Ambulatory Care Management.* 2005;28(2):141-156.

Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Medicine & Science in Sports & Exercise.* 2001;33(6 Suppl):S446-S451.

Bouchard C, Shephard RJ, Stephens T, (eds.). *Physical activity, fitness and health: International proceedings and consensus statement.* Champaign IL: Human Kinetics; 1994.

Brown WJ, Hockey R, Dobson AJ. Physical activity, body mass index and health care costs in mid-age Australian women. *Australian and New Zealand Journal of Public Health.* 2008;32(2):150-155.

Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, Wagner EH. The effect of strength and endurance training on gait, balance, fall risk and health services use in community-living older adults. *Journal of Gerontology.* 1997;52A(4):M218-M224.

Bursac Z, Gauss CH, Williams DK, Hosmer D. Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine.* 2008;3(1):17.

Canadian Cancer Society's Advisory Committee on Cancer Statistics. *Canadian Cancer Statistics 2013*. Toronto, ON: Canadian Cancer Society; 2013.

Canadian Diabetes Association. *The cost of diabetes in Canada: The economic tsunami.* Toronto, ON: Canadian Diabetes Association; 2009.

Canadian Fitness & Lifestyle Research Institute. *Physical Activity Levels of Canadians - 2008 Physical Activity Monitor*. 2010; http://cflri.ca/. Accessed July 17, 2013.

Canadian Institute for Health Information. *CIHI Annual Report, 2012-2013: Better data. Better decisions. Healthier Canadians.* Ottawa, ON;2013.

Canadian Institute for Health Information. *CIHI Data and Standards: Day Procedure Groups (DPG)*. 2010; http://www.cihi.ca/CIHI-ext-portal/internet/en/document/standards+and+data+submission/standards/case+mix/casemix_dpg.

Canadian Institute for Health Information. *Health care in Canada, 2011. A Focus on Seniors and Aging.* Ottawa, ON;2011.

Canadian Institute for Health Information. *Seniors and the Health Care System: What is the Impact of Multiple Chronic Conditions?* Ottawa, ON;2011.

Caruso C, Lio D, Cavallone L, Franceschi C. Aging, longevity, inflammation, and cancer. *Annals of the New York Academy of Sciences.* 2004;1028(1):1-13.

Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports.* 1985;100(2):126-131.

Chad KE, Reeder BA, Harrison EL, et al. Profile of physical activity levels in community-dwelling older adults. *Medicine & Science in Sports & Exercise.* 2005;37(10):1774-1784.

Chang AM, Halter JB. Aging and insulin secretion. *American Journal of Physiology - Endocrinology And Metabolism.* 2003;284(1):E7-E12.

Chen H, Zhou X, Fujita H, Onozuka M, Kubo K-Y. Age-related changes in trabecular and cortical bone microstructure. *International Journal of Endocrinology.* 2013; Article ID 213234, 9 pages.

Chen IJ, Chou CL, Yu S, Cheng SP. Health services utilization and cost utility analysis of a walking program for residential community elderly. *Nursing Economics.* 2008;26(4):263-269.

Chief Public Health Officer of Canada. *Report on the State of Public Health in Canada, 2010: Growing older - Adding life to years.* Ottawa, ON: Government of Canada; 2010.

Chodzko-Zajko W, Schwingel A, Park CH. Successful aging: The role of physical activity. *American Journal of Lifestyle Medicine.* 2009;3:20-28.

Clark AL, Fonarow GC, Horwich TB. Waist circumference, body mass index, and survival in systolic heart failure: The obesity paradox revisited. *Journal of Cardiac Failure.* 2011;17(5):374-380.

Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. *The Lancet.* 381:752-762.

Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports,.* 2011;22(1):7-14.

Concannon LG, Grierson MJ, Harrast MA. Exercise in the older adult: From the sedentary elderly to the masters athlete. *PM&R Journal.* 2012;4(11):833-839.

Copinschi G, Caufriez A. Sleep and hormonal changes in aging. *Endocrinology and Metabolism Clinics of North America.* 2013;42(2):371-389.

Copeland JL, Esliger DW. Accelerometer assessment of physical activity in active, healthy older adults. *Journal of Aging & Physical Activity.* 2009;17(1):17-30.

Costello E, Kafchinski M, Vrazel J, Sullivan P. Motivators, barriers, and beliefs regarding physical activity in an older adult population. *Journal of Geriatric Physical Therapy.* 2011;34(3):138-147.

Courtney M, Edwards H, Chang A, Parker A, Finlayson K, Hamilton K. Fewer emergency readmissions and better quality of life for older adults at risk of hospital readmission: A randomized controlled trial to determine the effectiveness of a 24-week exercise and telephone follow-up program. *Journal of the American Geriatrics Society.* 2009;57(3):395-402.

Craig CL. Evolution and devolution of national physical activity policy in Canada. *Journal of Physical Activity and Health.* 2011;8:1044-1056.

Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinková E, Vandewoude M, Zamboni M. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and Ageing.* 2010;39(4):412-423.

Dalgren G, Whitehead M. *Policies and Strategies to Promote Social Equity in Health.* Stockholm: Institutes for Futures Studies; 1991.

Daniels KM, Arena R, Lavie CJ, Forman DE. Cardiac rehabilitation for women across the lifespan. *The American Journal of Medicine.* 2012;125(9):937.e931-937.e937.

Davis JC, Bryan S, Marra CA, Sharma D, Chan A, Beattie BL, Graf P, Liu-Ambrose T. An economic evaluation of resistance training and aerobic training versus balance and toning exercises in older adults with mild cognitive impairment. *PLoS ONE.* 2013;8(5):e63031.

Davis JC, Marra CA, Robertson MC, Khan KM, Najafzadeh MA, Ashe MC, Liu-Ambrose T. Economic evaluation of dose–response resistance training in older women: A cost-effectiveness and cost-utility analysis. *Osteoporos International.* 2011;22(5):1355-1366.

Davis JC, Marra CA, Robertson MC, Najafzadeh MA, Liu-Ambrose T. Sustained economic benefit of resistance training in community-dwelling senior women. *Journal of the American Geriatrics Society.* 2011;59:1232-1237.

Degens H, Korhonen MT. Factors contributing to the variability in muscle ageing. *Maturitas.* 2012;73(3):197-201.

Demontiero O, Vidal C, Duque G. Aging and bone loss: New insights for the clinician. *Therapeutic Advances in Musculoskeletal Disease.* 2012;4(2):61-76.

Denkinger MD, Lukas A, Herbolsheimer F, Peter R, Nikolaus T. Physical activity and other health-related factors predict health care utilisation in older adults. *Zeitschrift für Gerontologie und Geriatrie.* 2012;45(4):290-297.

Depp CA, Jeste DV. Definitions and predictors of successful aging: A comprehensive review of larger quantitative studies. *American Journal of Geriatric Psychiatry.* 2006;14:6-20.

Depp C, Vahia IV, Jeste D. Successful aging: Focus on cognitive and emotional health. *Annual Review of Clinical Psychology.* 2010;6(1):527-550.

Diehr P, Yanez D, Ash A, Hornbrook M, Lin DY. Methods for analyzing health care utilization and costs. *Annual Review of Public Health.* 1999;20:125-144.

Dinger MK, Oman F, Taylor EL, Vesely SK, Able J. Stability and convergent validity of the Physical Activity Scale for the Elderly (PASE). *Journal of Sports Medicine and Physical Fitness.* 2004;44(186-192).

DiPietro L. Physical activity in aging: Changes in patterns and their relationship to health and function. *the journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2001;56(suppl 2):13-22.

Dorner TE, Reider A. Obesity paradox in elderly patients with cardiovascular diseases. *International Journal of Cardiology*. 2012;155(56-65).

Downey W, Beck P, McNutt M. Health databases in Saskatchewan. In: Strom BL, ed. *Pharmacoepidemiology*. Third ed. Chichester, NY: Wiley; 2000.

Dunlop S, Coyte PC, McIsaac W. Socio-economic status and the utilization of physicians' services: Results from the Canadian National Population Health Survey. *Social Science & Medicine.* 2000;51(2000):123-133.

Edouard L, Rawson NS. Reliability of the recording of hysterectomy in the Saskatchewan health care system. *British Journal of Obstetrics & Gynaecology.* 1996;103(9):891-897.

Edwards P, Mawani A. *Healthy Aging in Canada: A new vision, a vital investment from evidence to action. A background paper prepared for Federal, Provincial and Territorial Committee of Officials (Seniors)*. Ottawa, ON: Government of Canada; 2006.

Felson DT. An update on the pathogenesis and epidemiology of osteoarthritis. *Radiologic Clinics of North America.* 2004;42(1):1-9.

Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, Jordan JM, Kington RS, Lane NE, Nevitt MC, Zhang Y, Sowers M, McAlindon T, Spector TD, Poole AR, Yanovski SZ, Ateshian G, Sharma L, Buckwalter JA, Brandt KD, Fries JF. Osteoarthritis: New insights. Part 1: The disease and its risk factors. *Annals of Internal Medicine.* 2000;133(8):635-646.

Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, Abellan van Kan G, Andrieu S, Bauer J, Breuille D, Cederholm T, Chandler J, De Meynard C, Donini L, Harris T, Kannt A, Keime Guibert F, Onder G, Papanicolaou D, Rolland Y, Rooks D, Sieber C, Souhami E, Verlaan S, Zamboni M. Sarcopenia: An undiagnosed condition in older adults. Current consensus definition: Prevalence, etiology, and consequences. *Journal of the American Medical Directors Association.* 2011;12(4):249-256.

Fleg JL, J S. Age-associated changes in cardiovascular structure and function: A fertile milieu for future disease. *Heart Fail Rev.* 2012;17:545-554.

Fletcher GF, Blair SN, Blumenthal J, Caspersen C, Chaitman B, Epstein S. Sivarajan Froelicher ES, Froelicher VF, Pina IL, Pollock ML. Statement on exercise. Benefits and recommendations for physical activity programs for all Americans. A statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation.* 1992;86(1):340-344.

Foster C, Hillsdon M, Thorogood M, Kaur A, WedatilakeT. Interventions for promoting physical activity. *Cochrane Database of Systematic Reviews.* 2005 (updated 2013);Issue 1.

Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie MA. Frailty in Older Adults: Evidence for a Phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2001;56(3):M146-M157.

Fries JF. Aging, natural death, and the compression of morbidity. *New England Journal of Medicine.* 1980;303:130-135.

Fries JF. Successful aging - An emerging paradigm of gerontology. *Clinics in Geriatric Medicine.* 2002;18(3):371-382.

Garriguet D. Bone health: Osteoporosis, calcium and vitamin D. *Health Reports.* 2011;22(3).

Gennuso KP, Gangnon RE, Matthews CE, Thraen-Borowski KM, Colbert LH. Sedentary behavior, physical activity and markers of health in older adults. *Medicine & Science in Sports & Exercise.* 2013;45(8):1493-1500.

Gielen E, Verschueren S, O'Neill TW, Pyr SR, O'Connell MD, Lee DM, Ravindrarajah R, Claessens F, Laurent M, Milisen K, Tournoy J, Dejaeger M, Wu FC, Vanderschueren D, Boonen S. Musculoskeletal frailty: A geriatric syndrome at the core of fracture occurrence in older age. *Calcified Tissue International.* 2012;91(3):161-177.

Gilmour H, Park J. Dependancy, chronic conditions and pain in seniors. *Health Reports.* 2006;16(Suppl):21-31.

Girodano R, Bonelli L, Marinazzo E, Ghigo E, Arvat E. Growth hormone treatment in human ageing: Benefits and risks. *Hormones.* 2008;7(2):133-139.

Guilcher SJT, Craven BC, McColl MA, Lemieux-Charles L, Casciaro T, Jaglal SB. Application of the Andersen's health care utilization framework to secondary complications of spinal cord injury: a scoping review. *Disability and Rehabilitation.* 2012;34(7):531-541.

Haapanen-Niemi N, Miilunpalo S, Vuori I, Pasanen M, Oja P. The impact of smoking, alcohol consumption, and physical activity on use of hospital services. *American Journal of Public Health.* 1999;89(5):691-698.

Haggis C, Sims-Gould J, Winters M, Gutteridge K, McKay H. Sustained impact of community-based physical activity interventions: key elements for success. *BMC Public Health.* 2013;13(1):892.

Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: Updated recommendations for adults from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116:1081-1093.

Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for children*. Cat. No. H39-646/2002-2E. Ottawa, ON: Health Canada; 2002.

Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for older adults*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1999.

Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide for youth*. Cat. No. H39-611/2002-2E. Ottawa, ON: Health Canada; 2002.

Health Canada, Canadian Society for Exercise Physiology. *Canada's physical activity guide to healthy active living*. Cat. No. H39-429/1999-1E. Ottawa, ON: Health Canada; 1998.

Heart & Stroke Foundation of Canada. *Position Statement on Physical Activity*. Ottawa, ON: Heart & Stroke Foundation of Canada; 1993.

Heckman GA, McKelvie RS. Cardiovascular aging and exercise in healthy older adults. *Clinical Journal of Sport Medicine.* 2008;18(6):479-485.

Hedeker D, Gibbons RD. Application of random-effects pattern mixture models for missing data in longitudinal studies. *Psychological Methods.* 1997;2(64-78).

Herman KM, Ardern CI, Mason C, Brien SE, Katzmarzyk PT. Trends in physical activity research in Canada. *Applied Physiology, Nutrition, and Metabolism.* 2007;32(3):400-408.

Hertoghe T. The "multiple hormone deficiency" theory of aging: Is human senescence caused mainly by multiple hormone deficiencies? *Annals of the New York Academy of Sciences.* 2005;1057(1):448-465.

Hilbe JM. *Negative Binomial Regression.* Cambridge: Cambridge University Press; 2007.

Hoffe S, Balducci L. Cancer and age: General considerations. *Clinics in Geriatric Medicine.* 2012;28(1):1-18.

Holland SK, Greenberg J, Tidwell L, Malone J, Mullan J, Newcomer R. Community-based health coaching, exercise and health service utilization. *Journal of Aging and Health.* 2005;17(6):697-716.

Horstman AM, Dillon EL, Urban RJ, Sheffield-Moore M. The role of androgens and estrogens on healthy aging and longevity. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2012;67(11):1140-1152.

Hosmer DW, Lemeshow S. *Applied Logistic Regression.* New York: John Wiley & Sons, Inc; 2000.

Hotta H, Uchida S. Aging of the autonomic nervous system and possible improvements in autonomic activity using somatic afferent stimulation. *Geriatrics & Gerontology International.* 2010;10:S127-S136.

Huffman DM, Barzilai N. Role of visceral adipose tissue in aging. *Biochimica et Biophysica Acta (BBA) - General Subjects.* 2009;1790(10):1117-1123.

Ioannidis G, Papaioannou A, Hopman WM, Akhtar-Danesh N, Anastassiades T, Pickard L, Kennedy CC, Prior JC, Olszynski WP, Davison KS, Goltsman D, Thabane L, Gafni A, Papadimitropoulos, Brown JP, Josse RG, Hanley DA, Adachi JD. Relation between fractures and mortality: Results from the Canadian Multicentre Osteoporosis Study. *Canadian Medical Association Journal.* 2009;181(5):265-271.

Jacobs JM, Rottenberg Y, Cohen A, Stessman J. Physical activity and health service utilization among older people. *Journal of the American Medical Directors Association.* 2013;14(2):125-129.

Janssen I. Health care costs of physical inactivity in Canadian adults. *Applied Physiology, Nutrition, and Metabolism.* 2012;37(4):803-806.

Janssen I, Baumgartner RN, Ross R, Rosenberg IH, Roubenoff R. Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. *American Journal of Epidemiology.* 2004;159(4):413-421.

Janssen I, Shepard DS, Katzmarzyk PT, Roubenoff R. The healthcare costs of sarcopenia in the United States. *Journal of the American Geriatrics Society.* 2004;52(1):80-85.

Kalache A, Keller I. The WHO perspective on active ageing. *Promotion & Education.* 1999;6(4):20-23.

Kamel HK. Sarcopenia and aging. *Nutrition Reviews.* 2003;61(5):157-167.

Karazsia BT, van Dulmen MHM. Regression models for count data: illustrations using longitudinal predictors of childhood injury. *Journal of Pediatric Psychology.* November 1, 2008 2008;33(10):1076-1084.

Katzmarzyk PT, Gledhill N, Shephard RJ. The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal.* 2000;163(11):1435-1440.

Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: An update. *Canadian Journal of Applied Physiology.* 2004;29(1):90-115.

Katzmarzyk PT, Lear SA. Physical activity for obese individuals: a systematic review of effects on chronic disease risk factors. *Obesity Reviews.* 2012;13(2):95-105.

Keeler EB, Manning WG, Newhouse JP, Sloss EM, Wasserman J. The external costs of a sedentary lifestyle. *American Journal of Public Health.* 1989;79(8):975-981.

Kemmler W, von Stengel S, Engelke K, Häberle L, Kalender WA. Exercise effects on bone mineral density, falls, coronary risk factors, and health care costs in older women: The randomized controlled senior fitness and prevention (SEFIP) study. *Archives of Internal Medicine.* 2010;170(2):179-185.

Kesaniemi YA, Danforth E Jr, Jensen MD, Kopelman PG, Lefebvre P, Reeder BA. Dose-response issues concerning physical activity and health: An evidence-based symposium. *Medicine & Science in Sports & Exercise.* 2001;33(6Suppl):S351-358.

King AC, King DK. Physical activity for an aging population. *Public Health Reviews.* 2010;32(2):401-426.

King AC, Rejeski WJ, Buchner DM. Physical activity interventions targeting older adults: A critical review and recommendations. *American Journal of Preventive Medicine.* 1998;15:316-333.

King M, Judge J, Whipple R, Wolfson L. Reliability and responsiveness of two physical performance measures examined in context of a functional training intervention. *Physical Therapy.* 2000;80(1):8-16.

Kirkwood TBL. Understanding the odd science of aging. *Cell.* 2005;120(4):437-447.

Kivitz A, Fairfax M, Sheldon EA, et al. Comparison of the effectiveness and tolerability of Lidocaine patch 5% versus Celecoxib for osteoarthritis-related knee pain: Post hoc analysis of a 12-week, prospective, randomized, active-controlled, open-label, parallel-group trial in adults. *Clinical Therapeutics* 2008;30(12):2366-2377.

Kohl HW, 3rd, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, Kahlmeier S. Physical Activity 5: The pandemic of physical inactivity: global action for public health. *The Lancet.* 2012;380(9838):294-305.

Kokkinos P. Physical Activity, Health Benefits, and Mortality Risk. *ISRN Cardiology.* 2012;2012:14.

Krentz AJ, Viljoen A, Sinclair A. Insulin resistance: A risk marker for disease and disability in the older person. *Diabetic Medicine.* 2013;30(5):535-548.

Kuriyama S, Hozawa A, Ohmori K, Suzuki Y, Nishino Y, Fujita K, Tsubono Y, Tsuji I. Joint impact of health risks on health care charges: 7-year follow-up of National Health Insurance beneficiaries in Japan (the Ohsaki Study). *Preventive Medicine.* 2004;39:1194-1199.

Lagace C, O'Donnell S, Diener A, Roberge H, Tanguay S. Chapter 6: Economic burden of arthritis. In: Public Health Agency of Canada, Arthritis Consumer Experts, Arthritis Community Research & Evaluation Unit, et al., eds. *Life with Arthritis in Canada, 2010*. Ottawa, ON: Public Health Agency of Canada; 2010.

Lai DWL. Intention of use of long-term care facilities and home support services by Chinese-Canadian family caregivers. *Social Work in Health Care.* 2008;47(3):259-276.

Lakatta EG. Age-associated cardiovascular changes in health: Impact on cardiovascular disease in older persons. *Heart Fail Rev.* 2002;7(1):1480.

Lakatta EG., Levy D. Arterial and cardiac aging: Major shareholders in cardiovascular disease enterprises. *Circulation.* 2003;107:346-354.

Lang PO, Michel JP, Zekry D. Frailty Syndrome: A transitional state in a dynamic process. *Gerontology.* 2009;55(5):539-549.

Lankenau B, Solari A, Pratt M. International physical activity policy development: A commentary. *Public Health Reports.* 2004;119(3):352-355.

Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair S, Katzmarzyk P. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet.* 2012;380:219-229.

Lee S-JL, Park S-H. Arterial ageing. *Korean Circulation Journal.* 2013;43:73-79.

Leigh JP, Fries JF. Health habits, health care use and costs in a sample of retirees. *Inquiry.* 1992;29(1):44-54.

Leon-Munoz LM, Guallar-Castillon P, Lopez Garcia E, Banegas JR, Gutierrez-Fisac JL, Rodriguez-Artalejo F. Relationship of BMI, waist circumference, and weight change with use of health services by older adults. *Obesity Research.* 2005;13(8):1398-1404.

Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika.* 1986;73(1):13-22.

Linden M, Horgas AL, Gilberg R, Steinhagen-Thiessen E. Predicting health care utilization in the very old: the role of physical health, mental health, attitudinal and social factors. *Journal of Aging and Health.* 1997;9(1):3-27.

Lindstrom B, Chad K, Ashworth N, et al. Effectiveness of recruitment strategies for a physical activity intervention in older adults. *Journal of Physical Activity & Health.* 2004;1(3):259-269.

Liu-Ambrose TY, Ashe MC, Marra C, Physical Activity and Chronic Conditions Research Team. Independent and inverse association of healthcare utilisation with physical activity in older adults with multiple chronic conditions. *British Journal of Sports Medicine.* 2010;44(14):1024-1028.

Lix LM, Walker R, Nesdole R, Yang J, Chen G, for the CHEP-ORTF Hypertension Outcomes and Surveillance Team. Features of physician services databases in Canada. *Chronic Diseases and Injuries in Canada.* 2012;32(4):186-193.

Loeser Jr RF, Delbono O. Chapter 112. Aging of the Muscles and Joints,. In: Halter JB, Ouslander JG, Tinetti ME, Studenski S, High KP, Asthana S, eds. *Hazzard's Geriatric Medicine and Gerontology*. 6th Edition ed. New York: McGraw-Hill; 2009.

Lohr SL. *Sampling: Design and Analysis.* 2nd Edition. Boston, MA: Cengage Learning, Inc.; 2010.

Lui L, Reeder B, Shuaib A, Mazagri R. Validity of stroke diagnosis on hospital discharge records in Saskatchewan, Canada: Implications for stroke surveillance. *Cerebrovascular Disease.* 1999;9(224-30).

Luppa M, Sikorski C, Motzek T, Konnopta A, Konig H-H, Reidel-Heller SG. Health service utilization and costs of depressive symptoms in late life - A systematic review. *Current Pharmaceutical Design.* 2012;18(36):5936-5957.

Manning WG, Keeler EB, Newhouse JP, Sloss EM, Wasserman J. *The Costs of Poor Health Habits.* Cambridge, MA: Harvard University Press; 1991.

Martel L, Belanger A, Berthelot J-M, Carriere Y. Healthy Aging. In: *Healthy today, Healthy tomorrow? Findings from the National Population Health Survey*. Ottawa, ON: Statistics Canada; 2005.

Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *Journal of Aging & Physical Activity.* 2006;14(4): 392-410.

Martinson BC, Crain AL, Pronk NP, O'Connor PJ, Maciosek MV. Changes in physical activity and short-term changes in health care charges: a prospective cohort of older adults. *Preventive Medicine.* 2003;37(319-326).

McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Nutrtition, Energy, and Human Performance.* 7th edition. Baltimore, MD: Lippincott Williams & Wilkins; 2009.

McColl M, Shortt S. Another way to look at high service utilization: The contribution of disability. *Journal of Health Services Research & Policy.* 2006;11(2):74-80.

Melzer K, Kayser B, Pichard C. Physical activity: The health benefits outweigh the risks. *Current Opinion in Clinical Nutrition & Metabolic Care.* 2004;7(6):641-647.

Metcalfe A, Williams J, McChesney J, Patten SB, Jette N. Use of complementary and alternative medicine by those with a chronic disease and the general population - Results of a national population based survey. *BMC Complementary & Alternative Medicine.* 2010;10:58.

Mirolla M. *The Cost of Chronic Disease in Canada.* Nova Scotia: GPI Atlantic;2004.

Mitchell TL, Gobbons LW, Devers SM, Earnest CP. Effects of cardiorespiratory fitness on healthcare utilization. *Medicine & Science in Sports & Exercise.* 2004;36(12):2088-2092.

Mitchell WK, Atherton PJ, Williams J, Larvin M, Lund JN, Narici M. Sarcopenia, dynapenia and the impact of advancing age on human skeletal muscle size and strength: A quantitative review. *Frontiers in Physiology.* 2012;260.

Mobasheri A, Mendes AF. Physiology and pathophysiology of musculoskeletal aging: Current research trends and future priorities. *Frontiers in Physiology.* 2013;4:1-2.

Moineddin R, Nie J, Wang L, Tracy CS, Upshur R. Measuring change in health status of older adults at the population level: The transition probability model. *BMC Health Services Research.* 2010;10(1):306.

Morin S, Lix LM, Azimaee M, Metge C, Caetano P, Leslie WD. Mortality rates after incident non-traumatic fractures in older men and women. *Osteoporosis International.* 2011;22(9):2439-2448.

Morris JN, Heady JA, Raffle PA, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. *Lancet.* 1953;265(6796):1111-1120.

Munro JF, Nicholl JP, Brazier JE, Davey R, Cochrane T. Cost effectiveness of a community based exercise programme in over 65 year olds: cluster randomized trial. *Journal of Epidemiology and Community Health.* 2004;58 (1004-1010).

Murphy SL. Review of physical activity measurement using accelerometers in older adults: Considerations for research design and conduct. *Preventive Medicine.* 2009;48(2):108-114.

Muscaritoli M, Anker SD, Argilés J, Aversa Z, Bauer JM, Biolo G, Boirie Y, Bosaeus I, Cederholm T, Costelli P, Fearon KC, Laviano A, Maggio M, Rossi Fanelli F, Schneider SM, Schols A, Sieber CC. Consensus definition of sarcopenia, cachexia and pre-cachexia: Joint document elaborated by Special Interest Groups (SIG) "cachexia-anorexia in chronic wasting diseases" and "nutrition in geriatrics". *Clinical Nutrition.* 2010;29(2):154-159.

Nabalamba A, Miller WJ. Going to the doctor. *Health Reports.* 2007;18(1):23-35.

National Institute on Aging, National Institutes of Health, World Health Organization. *Global Health and Aging*. Geneva: World Health Organization; 2011.

National Seniors Council. *Report of the National Seniors Council on Volunteering Among Seniors and Positive and Active Aging.* Ottawa, ON: Government of Canada; 2010.

Naylor RM, Baker DJ, van Deursen JM. Senescent cells: A novel therapeutic target for aging and age-related diseases. *Clinical Pharmacology & Therapeutics.* 2013;93(1):105-116.

New England Research Institutes. *PASE: Physical Activity Scale for the Elderly. Administration and Scoring manual*. Watertown, MA: New England Research Institutes, Inc.; 1991.

Nguyen HQ, Ackermann RT, Berke EM, Cheadle A, Williams G, Lin E, Maciejewski ML, LoGerfo JP. Impact of a managed-Medicare physical activity benefit on health care utilization and costs in older adults with diabetes. *Diabetes Care.* 2007;30(1):43-48.

Nguyen HQ, Ackermann RT, Maciejewski M, Berke EM, Patrick M, Williams B, LoGerfo JP. Managed-Medicare health club benefit and reduced health care costs among older adults. *Preventing Chronic Disease.* 2008;5(1):1-10.

Niccoli T, Partridge L. Ageing as a risk factor for disease. *Current Biology.* 2012;22(7): R742-752.

North BJ, Sinclair DA. The intersection between aging and cardiovascular disease. *Circulation Research.* 2012;110(8):1097-1108.

Norton K, Norton L, Sadgrove D. Position statement on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport.* 2010;13(5):496-502.

Nusselder WJ, Peeters A. Successful aging: Measuring the years lived with functional loss. *Journal of Epidemiology and Community Health.* 2006;60:448-455.

Organization for Economic Co-operation and Development. *Health at a Glance 2011: OECD Indicators.* Paris, France: OECD Publishing;2011.

Osteoporosis Canada. Osteoporosis Facts & Statistics. 2013; http://www.osteoporosis.ca/osteoporosis-and-you/osteoporosis-facts-and-statistics/.

Paffenbarger RS Jr, Brand RJ, Sholtz RI, Jung DL. Energy expenditure, cigarette smoking, and blood pressure level as related to death from specific diseases. *American Journal of Epidemiology.* 1978;108(1):12-18.

Papaioannou A, Morin S, Cheung AM, Atkinson S, Brown JP, Feldman S, Hanley DA, Hodsman A, Jamal SA, Kaiser SM, Kvern B, Siminoski K, Leslie WD. 2010 Clinical practice guidelines for the diagnosis and management of osteoporosis in Canada: A summary. *Canadian Medical Association Journal.* 2010;182(17):1864-1873.

Park J. Use of alternative health care. *Health Reports.* 2005;16(2):39-42.

Parker BA, Kalasky MJ, Proctor DN. Evidence for sex differences in cardiovascular aging and adaptive responses to physical activity. *European Journal of Applied Physiology.* 2010;110(2):235-246.

Paterson DH, Jones GR, Rice CL. Ageing and physical activity: Evidence to develop exercise recommendations for older adults. *Canadian Journal of Public Health.* 2007;98 (Suppl 2):S69-S108.

Paterson D, Warburton D. Physical activity and functional limitations in older adults: A systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):38.

Pauler DK, McCoy S, Moinpour C. Pattern mixture models for longitudinal quality of life studies in advance stage disease. *Statistics in Medicine.* 2003;22:795-809.

Peabody JW, Luck J, Jain S, Bertenthal D, Glassman P. Assessing the accuracy of administrative data in health information systems. *Medical Care.* 2004;42(11):1066-1072.

Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scandinavian Journal of Medicine & Science in Sports.* 2006;16(S1):3-63.

Pereira B, Ferreira MG. Sowing the seeds of cancer: Telomeres and age-associated tumorigenesis. *Current Opinion in Oncology.* 2013;25(1):93-98.

Perkins AJ, Clark DO. Assessing the association of walking with health services use and costs among socioeconomically disadvantaged older adults. *Preventive Medicine.* 2001;32(6):492.

Petrella RJ, Pedersen L, Cunningham DA, Koval JJ, Paterson DH. Physician contact with older community patients: Is there an association with physical fitness? *Preventive Medicine.* 1999;29(6):571.

Phillips KA, Morrison KR, Andersen R, LA A. Understanding the context of healthcare utilization: Assessing environmental and provider-related variables in the Behavioral Model of Utilization. *Health Services Research.* 1998;33(3):571-596.

Physical activity and cardiovascular health: NIH consensus development panel on physical activity and cardiovascular health. *JAMA.* 1996;276(3):241-246.

Plotnikoff RC, Karunamuni ND, Johnson JA, Kotovych M, Svenson LW. Health-related behaviours in adults with diabetes: Associations with health care utilization and costs. *Canadian Journal of Public Health.* 2008;99(3):227-231.

Pronk NP, Goodman MJ, O'Connaor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *Journal of the American Medical Association.* 1999;282(23):2235-2239.

Public Health Agency of Canada. Diabetes in Canada. Ottawa, ON: Public Health Agency of Canada; 2011.

Public Health Agency of Canada. The facts: Seniors and injury in Canada. *The Safe Living Guide - A guide to home safety for seniors*. Ottawa, ON: Public Health Agency of Canada; 2011.

Public Health Agency of Canada. Tracking Heart Disease & Stroke in Canada. Ottawa, ON: Government of Canada; 2009.

Public Health Agency of Canada, Canadian Institute for Health Information. *Obesity in Canada: A joint report from the Public Health Agency of Canada and the Canadian Institute for Health Information*. Ottawa, ON:2011.

Raina PS, Kirkland SA, Wolfson C, Szala-Meneok K, Griffith LE, Keshavarz H, Uniat J, Furlini L, Angus CL, Strople G, Pelletier A. Accessing health care utilization databases for health research: A Canadian longitudinal study on aging feasibility study. *Canadian Journal on Aging.* 2009;28(Special Issue 03):287-294.

Rankinen T, Bouchard C. Genetic differences in the relationships among physical activity, fitness, and health. In: Bouchard C, Blair SN, Haskell WL, eds. *Physical Activity and Health*. 2nd ed: Human Kinetics, Inc; 2012:381-408.

Ramage-Morin PL, Shields M, Martel L. Health-promoting factors and good health among Canadians in mid- to late life. *Health Reports.* 2010;21(3):45-53.

Rawson NSB, D'Arcy C. Assessing the validity of diagnostic information in administrative health care utilization data: experience in Saskatchewan. *Pharmacoepidemiology and Drug Safety*. 1998;7(6):389-398.

Rawson NSB, Malcolm E. *Validity of the recording of cholecystectomy and hysterectomy in the Saskatchewan Health care datafiles.* Saskatoon, SK: Pharmacoepidemiology Research Unit;1995.

Rawson NSB, Malcolm E. Validity of the recording of ischaemic heart disease and chronic obstructive pulmonary disease in the Saskatchewan health care datafiles. *Statistics in Medicine.* 1995;14(24):2627-2643.

Rawson NSB, Malcolm E, D'Arcy C. Reliability of the recording of schizophrenia and depressive disorder in the Saskatchewan health care datafiles. *Social Psychiatry and Psychiatric Epidemiology.* 1997;32(4):191-199.

Reeder BA, Chad KE, Harrison EL, Ashworth NL, Sheppard MS, Fisher KL, Bruner BG, Quinn BG, Pahwa P, Hossain MA. Saskatoon *in motion*: Class- versus home-based exercise intervention for older adults with chronic health conditions. *Journal of Physical Activity & Health.* 2008;5(1):74-87.

Reeder BA, Chad KE, Harrison EL, et al. Saskatoon *in motion*: 12-month follow-up of a class- versus home-based exercise intervention for older adults with chronic health conditions. *Canadian Journal of Public Health (submitted);* 2013.

Reid R, Evans R, Barer M, Sheps S, Kerluke K, McGrail K, Hertzman C, Pagliccia N. Conspicuous consumption: Characterizing high users of physician services in one Canadian province. *Journal of Health Services Research & Policy.* 2003;8(4):215-224.

Reuben D, Siu A. An objective measure of physical function of elderly outpatients: The Physical Performance Test. *Journal of the American Geriatrics Society.* 1990;38:1105-1112.

Rhodes RE, Mark RS, Temmel CP. Adult sedentary behavior: A systematic review. *American Journal of Preventive Medicine.* 2012;42(3):e3-e28.

Ricketts TC, Goldsmith LJ. Access in health services research: The battle of the frameworks. *Nursing Outlook.* 2005;53(6):274-280.

Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging & Physical Activity.* 1999;7:129-161.

Riley GF. Administrative and claims records as sources of health care cost data. *Medical Care.* 2009;477(7 Suppl 1):S51-S55.

Roos LL, Brownell M, Lix L, Roos NP, Walld R, MacWilliam L. From health to research: Privacy, methods, approaches. *Social Science & Medicine.* 2008;66:117-129.

Rowe JW, Kahn RL. Human aging: Usual and successful. *Science.* 1987;237:143-149.

Rowe JW, Kahn RL. Successful aging and disease prevention. *Advances in Renal Replacement Therapy.* 2000;7(1):70-77.

Ryan B, Stewart M, Campbell MK, Koval J, Thind A. Understanding adolescent and young adult use of family physician services: a cross-sectional analysis of the Canadian Community Health Survey. *BMC Family Practice.* 2011;12(1):118.

Sakuma K, Yamaguchi A. Sarcopenic obesity and endocrinal adaptation with age. *International Journal of Endocrinology.* 2013; Article ID 204164:1-12.

Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. *Annual Review of Public Health.* 2006;27:297-322.

Samsa G, Edelman D, Rothman ML, Williams GR, Lipscomb J, Matchar D. Determining clinically important differences in health status measures: A general approach with illustration to the Health Utilities Index Mark II. *Pharmacoeconomics.* 1999;15(2):141-151.

Sander M, Avlund K, Lauritzen M, Gottlieb T, Halliwell B, Stevnsner T, Wewer U, Bohr VA. Aging—From molecules to populations. *Mechanisms of Ageing and Development.* 2008;129(10):614-623.

Santos DA, Silva AM, Baptista F, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Experimental Gerontology*. 2012;47:908-912.

Sari N. A short walk a day shortens the hospital stay: Physical activity and the demand for hospital services for older adults. *Canadian Journal of Public Health.* 2010;101(5):385-389.

Sari N. Exercise, physical activity and healthcare utilization: A review of literature for older adults. *Maturitas.* 2011;70(3):285-289.

Sari N. Physical inactivity and its impact on healthcare utilization. *Health Economics.* 2009;18(8):885-901.

Saskatchewan Ministry of Health. *Health Services Databases: Information document.* Epidemiology & Research Unit Population Health Branch, ed. Regina, SK: Saskatchewan Ministry of Health; 2010.

Schneeweiss S, Avorn J. A review of uses of health care utilization databases for epidemiologic research on therapeutics. *Journal of Clinical Epidemiology.* 2005;58(4):323-337.

Schuit AJ, Schouten EG, Westerterp KR, Saris WHM. Validity of the Physical Activity Scale for the Elderly (PASE): According to energy expenditure assessed by the doubly labeled water method. *Journal of Clinical Epidemiology.* 1997;50(5):541-546.

Schulz R, Heckhausen J. A life span model of successful aging. *American Psychologist.* 1996;51(7):702-714.

Sedentary Behavior Research Network. Letter to the editor: Standardized use of the terms "sedentary" and "sedentary behaviours". *Applied Physiology, Nutrition & Metabolism.* 2012;37:540-542.

Shephard RJ. Employee health and fitness: The state of the art. *Preventive Medicine.* 1983;12(5):644-653.

Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine.* 2003;37(3):197-206.

Shephard RJ. Maximal oxygen intake and independence in old age. *British Journal of Sports Medicine.* May 1, 2009 2009;43(5):342-346.

Sherlock M, Toogood A. Aging and the growth hormone/insulin like growth factor-I axis. *Pituitary.* 2007;10(2):189-203.

Sibley L, Weiner J. An evaluation of access to health care services along the rural-urban continuum in Canada. *BMC Health Services Research.* 2011;11(1):20.

Singh MA. Exercise to prevent and treat functional disability. *Clinics in Geriatric Medicine.* 2002;18:431-462.

Smith TP, Kennedy SL, Smith M, Orent S, Fleshner M. Physiological improvements and health benefits during an exercise-based comprehensive rehabilitation program in medically complex patients. *Exercise Immunology Review.* 2006;12:86-96.

Sonntag WE, Csiszar A, deCabo R, Ferrucci L, Ungvari Z. Diverse roles of growth hormone and insulin-like growth factor-1 in mammalian aging: Progress and controversies. *Journal of Gerontology Series A: Biological Sciences and Medical Sciences.* 2012;67A(6):587-598.

Spirduso WW, Francis KL, MacRae PG. Physical function of older adults. In: Spirduso WW, ed. *Physical Dimensions of Aging.* 2nd ed. Champaign, IL: Human Kinetics; 2005:261-286.

Statistics Canada. *1998 National Population Health Survey*. Ottawa, ON: Health Statistics Division; 2001:12-15.

Statistics Canada. 2011 Census: Age and sex. *The Daily.* Tuesday, May 29, 2012.

Statistics Canada. *Canada Year Book 2012*. Ottawa: Statistics Canada; 2012.

Statistics Canada. *Canadian Community Health Survey Cycle 3.1 Final Questionnaire.* Ottawa, ON: Statistics Canada; 2005.

Statistics Canada. *Canadian Community Health Survey Cycle 3.1 Master Microdata File User Guide*. Ottawa, ON: Statistics Canada; 2006.

Statistics Canada. *Healthy People, Healthy Places*. Ottawa, ON: Statistics Canada; 2010.

Statistics Canada. *Leading Causes of Death in Canada*, 2009. Ottawa, ON: Statistics Canada; 2012.

Statistics Canada. Physical activity during leisure time, by age group and sex. CANSIM Table 105-0501. 2013; http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health77a-eng.htm. Accessed July 12, 2013.

Statistics Canada. *Population projections for Canada, provinces and territories*. Demography Division, ed. Ottawa, ON: Ministry of Industry, Government of Canada; 2010.

Statistics Canada. *Response Rates by Province/Territory and Health Region. CCHS Cycle 3.1.* Ottawa, ON: Statistics Canada; 2006.

Stein C, Moritz C, WHO's Ageing and Health. *A Life Course Perspective of Maintaining Independence in Older Age.* Geneva: World Health Organization; 1999.

Strain LA. Use of health services in later life: The influence of health beliefs. *Journal of Gerontology.* 1991;46(3):143-150.

Strait JB, Lakatta EG. Aging-associated cardiovascular changes and their relationship to heart failure. *Heart Failure Clinics.* 2012;8(1):143-164.

Sung MY, Dyck JB. Age-related cardiovascular disease and the beneficial effects of calorie restriction. *Heart Fail Rev.* 2012/09/01 2012;17(4-5):707-719.

Suri P, Morgenroth DC, Hunter DJ. Epidemiology of osteoarthritis and associated comorbidities. *PM&R.* 2012;4(5, Supplement):S10-S19.

Svege I, Kolle E, Risberg M. Reliability and validity of the Physical Activity Scale for the Elderly (PASE) in patients with hip osteoarthritis. *BMC Musculoskeletal Disorders.* 2012;13(1):26.

Swift DL, Lavie CJ, Johannsen NM, Arena R, Earnest CP, O'Keefe JH, Milani RV, Blair SN, Church TS. Physical activity, cardiorespiratory fitness, and exercise training in primary and secondary coronary prevention. *Circulation Journal.* 2013;77(2):281-292.

Tajeu GS, Delzell E, Smith W, Arora T, Curtis JR, Saag KG, Morrisey MA, Yun H, Kilgore ML. Death, debility, and destitution following hip fracture. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences.* 2014;69(3): 346-353.

Tarride JE, Hopkins RB, Leslie WD, Morin S, Adachi JD, Papaioannou A, Bessette L, Brown JP, Goeree R. The burden of illness of osteoporosis in Canada. *Osteoporos International.* 2012;23(11):2591-2600.

Taylor MG. *Health Insurance and Canadian Public Policy: The Seven Decisions That Created the Health Insurance System and Their Outcomes.* Montreal & Kingston: McGill-Queen's University Press; 2009.

Tbachnick BG, Fidell LS. *Using Multivariate Statistics.* Boston, MA: Pearson Education Inc; 2007.

Tchernof A, Despres JP. Pathophysiology of human visceral obesity: An update. *Physiological Reviews.* 2013;93:359-404.

Tennis P, Bombardier C, Malcolm E, Downey W. Validity of rheumatoid arthritis diagnoses listed in the Saskatchewan hospital separations database. *Journal of Clinical Epidemiology.* 1993;46(7):675-683.

Topp R, Fahlman M, Boardley D. Healthy aging: Health promotion and disease prevention. *Nursing Clinics of North America.* 2004;39:411-422.

Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism.* 2010;35(6):725-740.

Tremblay MS, Shephard RJ, Brawley LR. Research that informs Canada’s physical activity guides: an introduction. *Applied Physiology, Nutrition & Metabolism.* 2007;32:S1-S8.

Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE, Kho ME, Hicks A, LeBlanc AG, Zehr L, Murumets K, Duggan M. New Canadian physical activity guidelines. *Applied Physiology, Nutrition & Metabolism.* 2011;36:36-46.

Tricco AC, Pham B, Rawson NSB. Manitoba and Saskatchewan administrative health care utilization databases are used differently to answer epidemiologic research questions. *Journal of Clinical Epidemiology.* 2008;61(2):192-197.e112.

Turcotte M, Schellenberg G. *A Portrait of Seniors in Canada*. Ottawa, ON: Statistics Canada; 2007.

Twisk JWR. *Applied Longitudinal Data Analysis for Epidemiology - A Practical Guide.* Cambridge: Cambridge University Press; 2003.

United Nations Department of Economic and Social Affairs Population Division. World population ageing 1950-2050. New York: United Nations 2002.

United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council of Physical Fitness and Sport. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: United States Department of Health and Human Services; 1996.

Vahia IV, Thompson WK, Depp CA, Allison M, Jeste DV. Developing a dimensional model for successful cognitive and emotional aging. *International Psychogeriatrics.* 2012;24(04):515-523.

van Walraven C, Austin P. Administrative database research has unique characteristics that can risk biased results. *Journal of Clinical Epidemiology.* 2012;65:126-131.

van Walraven C, Bennett C, Forster AJ. Administrative database research infrequently used validated diagnostic or procedural codes. *Journal of Clinical Epidemiology.* 2011; 64(10):1054-1059.

Vegda K, Nie J, Wang L, Tracy CS, Moineddin R, Upshur R. Trends in health services utilization, medication use, and health conditions among older adults: a 2-year retrospective chart review in a primary care practice. *BMC Health Services Research.* 2009;9(1):217.

Verghese J, Wang C, Xue X, Holtzer R. Self-reported difficulty in climbing up or down stairs in non-disabled elderly. *Archives of Physical Medicine and Rehabilitation.* 2008;89(1):100-104.

Viljoen A, Sinclair AJ. Diabetes and insulin resistance in older people. *Medical Clinics of North America.* 2011;95:615-629.

Vina J, Sanchis-Gomar F, Martinez-Bello V, Gomez-Cabrera MC. Exercise acts as a drug; the pharmacological benefits of exercise. *British Journal of Pharmacology.* 2012;167(1):1-12.

Virnig BA, McBean M. Administrative data for public health surveillance and planning. *Annual Review of Public Health.* 2001;22:213-230.

Vitetta L, Anton B. Lifestyle and nutrition, caloric restriction, mitochondrial health and hormones: Scientific interventions for anti-aging. *Clinical Interventions in Aging.* 2007;2(4):537-543.

von Faber M, Bootsma–van der Wiel A, van Exel E, Gussekloo J, Lagaay AM, von Dongen E, Knook DL, van der Geest S, Westendorp RG. Successful aging in the oldest old: Who can be characterized as successfully aged? *Archives of Internal Medicine.* 2001;161(22):2694-2700.

Vuori I. Exercise and physical health: Musculoskeletal health and functional capabilities. *Research Quarterly for Exercise and Sport.* 1995;66(4):276-285.

Walston JD. Sarcopenia in older adults. *Current Opinion in Rheumatology.* 2012;24(6): 623-627.

Wang F, McDonald T, Reffitt B, Edington DW. BMI, physical activity, and health care utilization/costs among Medicare retirees. *Obesity Research.* 2005;13(8):1450-1457.

Warburton D, Charlesworth S, Ivey A, Nettlefold L, Bredin S. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *International Journal of Behavioral Nutrition and Physical Activity.* 2010;7(1):39.

Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: The evidence. *Canadian Medical Association Journal.* 2006;174(6):801-809.

Warburton DER, Nicol CW, Bredin SSD. Prescribing exercise as preventive therapy. *Canadian Medical Association Journal.* 2006;174(7):961-974.

Ware JEJ, Kosinski M, Keller SD. A 12-Item short-form health survey: Construction of scales and preliminary tests of reliability and validity. *Medical Care.* 1996;34(3):220-233.

Ware JE, Kosinski M, Turner-Bowker DM, Gandek B. *How to Score Version 2 of the SF-12 Health Survey.* Lincoln, RI: QualityMetric Inc.; 2002.

Warriner AH, Saag KG. Osteoporosis diagnosis and medical treatment. *Orthopedic Clinics of North America.* 2013;44(2):125-135.

Washburn RA. Assessment of physical activity in older adults. *Research Quarterly for Exercise and Sport.* 2000;71:S79-S88.

Washburn RA, McAuley E, Katula J, Mihalko SL, Boileau RA. The Physical Activity Scale for the Elderly (PASE): Evidence for validity. *Journal of Clinical Epidemiology.* 1999;52(7):643-651.

Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): Development and evaluation. *Journal of Clinical Epidemiology.* 1993;46(2):153-162.

Webb RC, Inscho EW. Age-related changes in the cardiovascular system. In: LM P, ed. *Hypertension in the Elderly*. New York: Springer-Verlag 2010.

West SL, Richter A, Melfi CA, McNutt M, Nennstiel ME, Mauskopf JA. Assessing the Saskatchewan database for outcomes research studies of depression and its treatment. *Journal of Clinical Epidemiology.* 2000;53(823-831).

Whitehead M, Dahlgren G, Gilson L. Developing the policy response to inequities in health: a global perspective. *Challenging Inequities in Health: From Ethics to Action.* 2001:314-315.

Willis BL, Gao A, Leonard D, DeFina LF, Berry JD. Midlife fitness and the development of chronic conditions in later life. *Archives of Internal Medicine.* 2012;172(17):1333-1340.

Woolcott JC, Ashe MC, Millar WC, Shi P, Marra CA, PACC Research Team. Does physical activity reduce seniors' need for healthcare? A study of 24 281 Canadians. *British Journal of Sports Medicine.* 2010;44:902-904.

Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bulletin of the World Health Organization.* 2003;81(9):646-656.

World Health Organization. *A Life Course Approach to Health.* Geneva: World Health Organization; 2000.

World Health Organization Ageing and Health Programme. The Heidleberg Guidelines for promoting physical activity among older persons. Geneva: World Health Organization; 1996.

World Health Organization Noncommunicable Diseases and Mental Health Cluster, Noncommunicable Disease Prevention and Health Promotion Department, Ageing and Life Course. *Active Ageing: A Policy Framework.* Geneva: World Health Organization; 2002.

Yaacob WFW, Lazim MA, Wah YB. A practical approach in modeling count data. *Proceedings of the Regional Conference on Statistical Sciences 2010*. Malaysia: Malaysia Institute of Statistics; 2010.

Yip AM, Kephart G, Rockwood K. Linkage of the Canadian Study of Health and Aging to provincial administrative health care databases in Nova Scotia. *International Psychogeriatrics.* 2001;13(SupplementS1):147-158.

APPENDICES

A-1 Project Proposal submitted to Saskatchewan Ministry of Health Data Access Review Committee

A-2 Agreement with Saskatchewan Ministry of Health, including approved technical description of data requirements

B-1 Application for access to the Saskatchewan Research Data Centre (SKY-RDC)

B-2 SSHRC Letter of Approval for access to SKY-RDC

B-3 Description of control variables for Study 1

C-1 50 + *in motion* intervention outcome data

C-2 Study 2 Supplementary Data and Analytical Tables

APPENDIX A-1

Project Proposal submitted to Saskatchewan Ministry of Health

Data Access Review Committee

RESEARCH PROPOSAL

Physical Activity, Physical Function and Quality of Life in Older Adults (50+) with Chronic Disease: The Impact on Health Care Utilization and Health Care Costs

Investigators:

1. Karen Chad, PhD, Professor, College of Kinesiology, University of Saskatchewan.

Address: College of Kinesiology
105 Gymnasium Place
Saskatoon, SK S7N 5C2
Tel: (306) 966-6511   Fax: (306) 966-6502
e-mail: chadk@duke.usask.ca

2. Liz Harrison, PhD, Professor and Director, School of Physical Therapy, University of Saskatchewan.

3. Anne PausJenssen, MD, MSc, Department of Medicine, Royal University Hospital

4. Bruce Reeder, MD, MSc, Professor and Head, Department of Community Health and Epidemiology, University of Saskatchewan.

5. Laurel Duczek, Director, Strategic Health Information and Planning Services (SHIPS), Saskatoon Health Region

'Saskatoon In Motion' is a multi-disciplinary research program funded by the Canadian Institute of Health Research (Community Alliances for Health Research) to evaluate the promotion of physical activity in a community setting and subsequent issues around building community capacity and health promotion. The 'Saskatoon In Motion' research program is based on equal and active partnerships between community organizations (Saskatoon Health Region and the City of Saskatoon Community Services Department) and researchers affiliated with the University of Saskatchewan. The research will lay the groundwork for an interdisciplinary approach for conducting physical activity and health research, training the next generation of researchers within a rigorous intellectual and applied context, and to demonstrate the best practice in community-university partnership for research dissemination and policy making.

Significance of the Study:

It is timely to examine the relative benefits and cost-effectiveness of a community-based vs. class-based program to increase physical activity among older adults with chronic health conditions. This study proposes to use unique population health data from the Province of Saskatchewan to better understand the impact of physical activity program on health status and health care utilization and costs in a growing population of older adults with chronic disease.

Background:

Extensive work has been done to show the positive impact of reducing the decline of physical activity on health status. (Booth et al., 2000; Dunn et al., 1999; King, et al., 1999; Frankish et al., 1998; Katz et al., 1983) It has been well documented in the literature that including physical activity as a preventive health measure at all levels in the health care continuum may effectively promote healthy aging and reduce health care costs. The limiting effects of age-related disease or disabilities may be overridden or suppressed by active living, even though the impairment is not eliminated. Increased functional demand, obtained through regular physical activity, produces physiological adaptive and self-regulating mechanisms, which increase performance and functional capacity. These outcomes, in turn, may evoke feelings of well-being and self-efficacy, and reduce the burden of a substantial period of dependent living (Katz et al., 1983).

Although the benefits of active living among those 50 years and older have been well established, physical activity levels among older age groups remain very low. For example, less than one third of Canadians aged 45 to 64 years and less than one quarter aged 65 years or more were active in 1995, compared to over half those aged 18 to 24 years (54%). Decreases in physical activity and function are well known as associated with the aging process.

Home- or community-based programs have been shown to be as effective as more formalized and structured, class-based programs at increasing physical activity and fitness among healthy sedentary middle-aged adults (Dunn et al., 1999). Furthermore, it has been proposed that home or community-based programs may be more successful in ensuring maintenance of the higher level of physical activity (King et al., 1995) as over two thirds of older adults prefer to exercise on their own with some instruction than in an exercise class (King et al., 2000; Wilcox et al.,1999). To date however, although there is accumulating evidence that class-based exercise programs are able to increase levels of physical activity among healthy sedentary older adults, modest experience exists with community-based programs in this age group and programs for those with chronic health conditions (King et al., 1998; Stewart et al., 1997). Furthermore, the cost-effectiveness of these two types of physical activity programs is not known.

Objectives:

The objectives of this study are to determine:

1. The level of physical activity, physical function and quality of life in individuals who participate in community and class-based programs.
2. The total cost per participant and the cost per unit of outcome (physical activity, physical function, quality of life) in community-based and class-based programs.
3. The use and cost of health services (e.g. physician services, hospitalizations, prescription drug services) by individuals in community-based and class-based programs.

The third objective requires access and analysis of databases external to the researchers and is the focus of this proposal.

Methods:

Research Design

This study is a randomized trial to examine the relative benefits and cost-effectiveness of a community-based versus class-based exercise program to increase physical activity, functional status, and quality of life among older adults with chronic health conditions.

Inclusion criteria
All study participants will be recruited from within the city of Saskatoon and will have been diagnosed by their physician with one of the following chronic diseases: Type 2 diabetes mellitus, hypertension, hyperlipidemia, overweight or obesity, or osteoarthritis. Subjects will be excluded from the study if they have a history of cardiac disease, stroke, or any medical condition that would preclude carrying out a moderate level physical activity program. A general screening tool including the PARmed-X will be completed by each potential subject and this will be used as a first step in identifying any potential medical problems.

Estimate of Study Population
Approximately 165 male and female community-dwelling older adults aged 50-85.

Analysis:
In the analysis, we will be comparing the use and cost of health services between individuals in the community-based physical activity program versus the center-based program. Second, we will compare the use and cost of health services prior to enrolment in the study (ie. inactive lifestyle) versus post participation in a physical activity program. Thirdly, the use and cost of health services within specific disease conditions will be investigated.

In addition, the relationship between health services and the other dependent study variables will be investigated. The dependent variables are in the domains of: physical activity (activity logs), health status (SF-12 and Sickness Impact Profile), quality of life (Quality of Life), function (specific outcome measures) and psycho-social indicators.

Data Sources Requested:

We propose to use health care data files from Saskatchewan Health to examine the impact of two physical activity programs on the utilization of health services. The Saskatchewan Health Care data files are a unique and comprehensive source of data on health care utilization of the population of the province of Saskatchewan and they allow for the tracking of health utilization by individuals over time.

The following data files contain relevant information related to the study questions:

- the *Health Registration/Population Registry* datafile which identifies individuals eligible for health services in Saskatchewan and provides basic demographic information;
- the *Medical Services* datafile which tracks fee-for-service physician utilization and diagnoses;
- the *Hospital Services* datafile which tracks hospital stays and length of stay; and
- the *Prescription Drug* datafile which tracks prescription drug usage.

Identifiable Data and Privacy

This study has been reviewed and approved by the University of Saskatchewan Advisory Committee on Ethics in Human Experimentation, Biomedical Sciences (September 2002). All study participants will be asked to provide consent to allow Saskatchewan Health to disclose identifying data to this project. (Appendix 1: Consent Form) During the data analysis stage and after data analysis is complete Dr. Karen Chad will assume responsibility for data security and storage. The data will be stored in a locked office on the University campus at all times during and after the study. A security code will be required to access the electronic data files. This code will only be provided to the individuals listed in this application. Data will be stored for a minimum of five years after the study has been completed.

GENERAL FEATURES

1. Time Period — September 1, 2001 to June 30, 2008
(period of one year prior to enrolment to five years after start of physical activity program – subjects were recruited into the study for the 10 month period September 1, 2002 and June 30 2003)

2. Data Files — Population registry
Hospital separation data (including day surgery records)
Physician services data
Outpatient prescription drug data

The hospital separation data will be used to identify all patients with a discharge diagnosis of or a procedure relating to one of the following conditions, where the patient was admitted to a Saskatchewan hospital between September 1, 2001 and June 30, 2008.

Qualifying records will have an ICD 10 code (or related ICD-9 code) as listed below in any of the first three discharge diagnosis fields AND/OR an identified CCP/CCI/FFS code in any of the first three procedures code fields.

For all qualifying subjects, an index date will be set to the date of enrolment into the study. The study termination date for each subject will be the earliest of the date of death, date of emigration from Saskatchewan, or 5 years after the index date.

3. Subjects — Approximately 165 males and females age 50+ enrolled in the study

For each subject,

- Demographic data will be compiled from the population registry.
- Hospital separation data will be compiled for the period beginning one year prior to the index date and 1, 2, 3, 4 and 5 years following the index date.
- Physician services and outpatient prescription drug data will be compiled for the period beginning one-year prior to the index date and 1,2, 3, 4 and 5 years following the index date.

DATA REQUIREMENTS

Subject File
Study ID number
Month and Year of Birth
Sex
Index date (equals the date of enrolment)
Registered Indian flag (because drug data are not available for registered Indians)
Study termination date (earliest of the date of death, date of emigration, or 5 years after the index date)
Death flag (will be set to “D” if study termination was due to death)

Hospital Separation File (all records for the period beginning one year prior to the index date and ending on the study termination date for all admissions)
Study ID number
Admission date
Discharge date
Diagnosis (up to 3 diagnostic codes to be provided; actual ICD-10 codes are provided below for the conditions of interest - i.e. chronic conditions that are affected by physical activity; otherwise, these fields can be left blank.)

Disease	**ICD-9 Code** *all subclassifications inclusive	**ICD-10 Code**
Depression	296; 300; 308; 309; 311	F32, F33
Osteoarthritis	715	M19, M15
Diabetes	250-251; 790.6 (hyperglycemia)	E10-E14
Retinopathy	250; 362; 440	H35
Other disorders of kidney and ureter	580-583; 587-593	N25-N29
Polyneuropathies and other disorders of the PNS	250; 350-359	G60-G64
Dyslipidemia	272	E78
Vascular Disease: Diseases of veins, lymph vessels and nodes	430-438; 451-459	I80-I89
Hypertension	401-405	I10-I15
Disease of arteries, arterioles, capillaries	440-448	I70-I79
Ischaemic Heart Disease	410-414	I20-I25
Other and unspecified disorders of Circulatory System	390-398; 415-417; 420-429	I95-I99; i46
Renal Failure	584-586	N17-N19
Obesity	278	E66
Stroke- Cerebrovascular Diseases	430-438	I60-I69

Note: This is a general listing of the ICD-9/10 codes of interest for this study. Some modifications (ie. additions or deletions) may be made to this list prior to the release of data.

Each of these conditions has been determined relevant for this study based on evidence that supports the influence of physical activity as a modifier on disease outcome.

Disease Condition	**Rationale**
Hypertension	As little as two weeks of aerobic exercise in previously sedentary adults decreases blood pressure (BP) in both hypertensive and normotensive subjects (Whelton et al., 2002). Similar changes in BP are seen in overweight and lean participants (Seamus et al., 2002, Fagard, 1999). Diet and exercise has a greater effect on reduction of BP, while exercise alone is still effective in reducing BP (Blumenthal et al., 2000).
Obesity	Exercise alone results in substantial reductions in body weight, total fat, abdominal fat and visceral fat in overweight or obese subjects (Ross & Janssen, 2001), while combined exercise and diet interventions result in greater weight loss than exercise alone (Bray, 2003, Wing, 1999). Exercise and diet weight loss as compared with diet only weight loss results in less lean body mass loss (Bray, 2003, Collazo-Clavell, 1999) as well as greater weight loss maintenance one year later (Miller et al. 1997). Exercise has a positive effect on health related quality of life and lower body pain in obese, older adults with osteoarthritis (Rejeski et al., 2002).
Osteoarthritis	Regular physical activity in the form of aerobic or resistance training reduces joint pain (Thomas et al., 2002; Sharkey et al., 2000; Kee, 2000, Deyle et al. 2000). Regular joint motion and weight-bearing exercise also protects cartilage and bone from atrophy (McCarberg & Herr, 2001), enhances activity performance, reduces disability (Ettinger et al., 1997) and improves quality of life (Sharkey et al., 2000).
Dyslipidemia	Both resistance training (Tucker & Silvester, 1996) and aerobic training (Carlson et al., 1999; Crouse et al., 1997) result in favourable changes in lipoprotein levels (Fahlam et al. 2002). Favourable lipoprotein changes can be achieved with low intensity walking (Tsetsonis & Hardman. 1995), and greatest improvements are seen with high amounts of exercise (equivalent to 27.6 to 29.2 km per week of jogging at a moderate pace) (Kraus et al., 2002). Middle-aged and older adults who are physically active have less atherogenic lipoprotein profiles than those that are sedentary (Carlson et al., 1999).
Diabetes	Both resistance and aerobic exercise have three major metabolic effects in type 2 diabetes: the independent role of exercise in reducing blood glucose levels (Fritz & Rosenquist, 2001; Tudor-Locke et al., 2000), the improvement in insulin sensitivity (Tudor-Locke et al., 2000) and the reduction in cardiovascular risk factors through improvement of the lipid profile (Walker et al., 1999), and reduction of blood pressure (Hamdy et al., 2001). Physical activity is also associated with a lower risk of cardiovascular disease and total mortality in men with type 2 Diabetes (Tanasescu et al., 2003).
Depression	Light, moderate and high-intensity aerobic and resistance exercise can reduce symptoms of depression (Dunn et al., 2001, Singh et al., 1997). Exercise may also be equally effective as antidepressants (Zoloft-seraltaline hydrochloride) at reducing depression among older patients, even though medication facilitates a more quick initial response (Blumenthal et al., 1999). A long-

	term physical activity regime reduces the risk of developing depressive symptoms in older adults (Lampinen et al., 2000)

Procedure (up to 3 procedure codes to be provided; actual CCP, CCI and FFS codes will be provided for the procedures of interest (i.e. relating to chronic conditions or complications); otherwise, these fields can be left blank)

Note: corresponding CCI and FFS codes will be provided.

Disease Condition	**Procedures**	**CCP Code * include all subcategories**	**CCI Code *include all subcategories**	**FFS Code**
Hypertension	Renal artery angiogram Renal artery stent/bypass	88.45 39.24		
Obesity		N/a		
Osteoarthritis	Arthroscopy Total hip replacement Total knee replacement	80.20-80.29 81.51 81.54-81.55		
Dyslipidemia		N/a		
Diabetes	Laser eye treatment Dialysis Coronary Bypass Graft Surgery Angioplasty- PTCA/stent Peripheral Angiogram Thrombolysis Atherectomy Vascular Surgery Aorto-fem bypass Abdominal aortic aneurysm repair Axillary-fem bypass Renal bypass Peripheral limb amputation	11.5 39.95; 54.98 36.10-36.14 39.5; 36.0 88.4 38.0-38.1 80.9 36.1;36.2;36.3 39.25 39.5; 54.72 39.29 39.24 84.0; 84.1		
Depression	Electroconvulsive Therapy (ECT), Psychotherapy, Phototherapy	94.27		
Ischemic Heart Disease	Coronary bypass surgery PTCA/stent	36.10-36.14 36.0-36.9		

Accident code
Discharge type
Date of procedure
Costs associated with hospital stay and procedures

Physician Visits File

(all records for the period beginning one year prior to the index date and ending on the study termination date; records will be collapsed into visits based on the following fields: health services number, service date, diagnosis, physician identification number and clinic number)

Study ID number
Physician type (categorized as primary care or specialist)
Service date (will be used to exclude physicians' visits to hospitals by comparing the service date with the hospital admission/separation dates)
Diagnosis (actual ICD-10 codes are provided for diseases of interest; otherwise this field can be left blank
Costs associated with physician visit

Prescription Drug File (for drugs of interest only listed below; for the period beginning one year prior to the index date and ending on the study termination date)

Study ID number
Drug category (drugs of interest are categorized in the table below)
Dispensing date
Cost associated with drugs dispensed

Disease	Drug Category
Obesity	Sibutramine, Orlistat
Hypertension	Antihypertensives, Cardiac drugs, Diuretics, Beta blockers, Sympathetic nerve inhibitors, Vasodilators, Angiotensin converting enzyme (ACE) inhibitors, Angiotensin II receptor blockers, Calcium antagonists/ calcium channel blockers. nitroglycerine and other nitrates, platelet inhibitory, anticoagulant drugs, and hemorrheologic agents; cholesterol-lowering: lovastatin, colestipol, cholestyramine, gemfibrozil, niacin; digitalis drugs.
Dyslipidemia	Statin drugs, Fibrates, Resins, Cholesterol absoption inhibitors, Niacin (nicotinic acid), Bile Acid Sequestrants
Diabetes	**First class**: Sulfonylurea, 1st gen: Chlorpropamide; 2nd gen: Glipizide, Glyburide, Glimepiride, Repaglinide **Second class**: Metformin, Thiazolidinediones **Third class**: alpha-glucosidase inhibitors; **Insulin**
Osteoarthritis	NSAIDs, Viscosupplementation, Hyaluronic acid, Glucosamine sulfate, chondroitin sulfate, Capsaicin
Depression	Antidepressant medication therapy: Selective serotonin reuptake inhibitors (SSRIs), Tricyclic antidepressants or monoamine oxidase inhibitors (MAOIs), St. John's wort (Hypericum perforatum). Electroconvulsive Therapy (ECT), Psychotherapy, Light (Phototherapy)

<u>*Data Linkage:*</u>

In order to determine the relationships between dependent variables (such as physical measures) it is necessary to link individual data with the corresponding individual health services data. For example, one question of importance is the relationship between SF-12 scores, physical activity levels and the use of health services, such as physician visits and hospitalizations. One may hypothesize that individuals with higher SF-12 scores should have higher physical activity levels and use fewer health services. To analyse this hypothesis one must have ability to link the researchers' database to the health services database.

The study database includes the dependent variables described previously. Databases currently being used to store subject data include: Microsoft Excel and SPSS for Windows. Subjects are identified by unique study ID number. The ID number can be linked back to study participants through a confidential participant registry that is maintained in a secure data location as described. This registry includes subject data including name and Saskatchewan Health Number.

The unique study ID number and the Sask Health Number will be used for data linkage. Sask Health will identify the information compiled using the unique study ID number.

Dissemination of Analysis:

The results will be disseminated to appropriate audiences through effective means and using appropriate formats (e.g. journal articles, conference presentations, etc.). These means will serve as a conduit for the transfer of technical and theoretical expertise from the university to the community, and transfer of practice-based knowledge from the community to the university. Individual names of participants will be kept anonymous. Results will not be presented individually, but as a group. A copy of any reports resulting from this study also will be made available to the participants and the Province as per the written obligations around reporting results that utilize Saskatchewan Health data.

Confidentiality and Security of Data:

Administrative, technical, and physical safeguards will be used to protect the confidentiality and security of the requested data. The following will be in place and a list of individuals who will be access data will be provided:

1. Locked and controlled access to designated area;
2. Backup copies of Confidential Information stored in a secure area;
3. Automatic shutdown procedures for terminals not in use;
4. A personalized security pass code for each authorized personnel;
5. Confidential information not to be removed from designated area;
6. Confidential information not to be available or accessible to unauthorized persons while in active use;
7. Confidential information returned to the designated, secured area following active use.

References

Blumenthal, J.A., Babyak, M.A., Moore, K.A., Craighead, W.E., Herman, S., Khatri, P., et al. (1999). Effects of exercise training on older patients with major depression. *Archives of Internal Medicine*, 159, 2319-2356.

Blumenthal, J.A., Sherwood, A., Gullette, E.C.D., Babyak, M., Waugh, R., Georgiades et al. (2000). Exercise and weight loss reduce blood pressure in men and women with mild hypertension. *Archive of Internal Medicine*, 160, 1947-1958.

Bray, G.A. (2003, January 17). Role of physical activity and exercise in obesity. *UpToDate*, Article 11.1. Retrieved June 9, 2003, from http://www.uptodate.com/patient_info/topicpages/ObesityHome.htm

Carlsson, C.M., Carnes, M., McBride, P.E., & Stein, J.H. (1999). Managing dyslipidemia in older adults. *Journal of the American Geriatrics Society,* 47, 1458-1465.

Collazo-Clavell, M.L (1999). Safe and effective management of the obese patient. Mayo Clinic Proceedings, 74, 1255-1260.

Crouse, S.F, O'Brien, B.C., Grandjen, P.W., Lowe, R.C., Rohack, J.J. & Green, J.S. (1997). Effects of training and a single session of exercise on lipids and apolipoproteins in hypercholesterolemic men. *Journal of Applied Physiology*, 83(6), 2019-2028.

Deyle, G.D., Henderson, N.E., Matekel, R.L., Ryder, M.G., Garber, M.B., & Allison, S.C. (2000). Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee. *Annals of Internal Medicine*, 132(3), 173-181.

Dunn, A.L., Trivedi, M.H., & O'Neal, H. (2000). Physical activity dose-response effects on outcomes of depression and anxiety. *Medicine and Science in Sports and Exercise*, 33(6), S587-597.

Ettinger, W.H., Burns, R., Messier, S., Applegate, W., Rejeski, W.J., Morgan, T., et a. (1997) A randomized controlled trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. *JAMA*, 27(1), 25-31.

Fagard, R.H. (1999). Physical activity in the preventio and treatment of hypertension in the obese. *Medicine & Science in Sports & Exercise* 31(11), S624-38.

Fahlman, M.M, Boardley, D., Lambert, C.P., & Flynn, M.G. (2002). Effects of endurance training and resistance training on plasma lipoprotein profiles in elderly women. Journal of Gerontology, 57A(2), B54-B60.

Fritz, T. & Rosenqvist, U. (2001). Walking for exercise- immediate effect on blood glucose levels in type 2 diabetes. *Scandinavian Journal of Primary Health Care,* 19, 31-33.

Hamdy, O., Goodyear, L.J., & Horton, E.S. (2001). Diet and exercise in type 2 diabetes mellitus. *Endocrinology and Metabolism Clinics of North America*, 30, 883-907.

Kee, C.C. (2000). Osteoarthritis: Manageable scourge of aging. *Nursing Clinic of North America*, 35(1), 199-208.

Kraus, W.E., Houmard, J.A., Duscha, B.D., Knetzger, K.J., Wharton, M.B., McCartney, J.S., et al. (2002). Effects of the amount and intensity of exercise on plasma lipoproteins. *New England Journal of Medicine,* 347(19), 1483-1492.

Lampinen, P., Heikkinen, R., & Ruoppila, I. (2000). Changes in intensity of physical exercise as predictors of depressive symptoms among older adults: An eight-year follow-up. *Preventative Medicine*, 30, 371-380.

McCarberg, B.H. & Herr, K.A. (2001) Osteoarthritis: How to manage and improve patient function. *Geriatrics*, 56(10), 14-24.

Miller, W.C., Koceja, D.M., & Hamilton, E.J. (1997) A meta-analysis of the past 25 years of weight loss research using diet, exercise or diet plus exercise intervention. *International Journal of Obesity*, 21, 941-947.

Rejeski, W.J., Focht, B.C., Messier, S.P., Morgan, T., Pahor, M., & Penninx, B. (2002). Obese, older adults with knee osteoarthritis: weight loss, exercise, and quality of life. Health Psychology, 21 (5), 419-426.

Ross, R. & Janssen, I. (2001). Physical activity, total and regional obesity: Dose-response considerations. *Medicine & Science in Sports & Exercise*, 33(6 Suppl), S521-S527.

Sharkey, N.A., Williams, N.I., & Guerin, J.B. (2000). The role of exercise in the prevention and treatment of osteoporosis and osteoarthritis. *Nursing Clinic of North America*, 35(1), 209-221.

Singh, N.A., Clements, K., & Fiatarone, M.A. (1997). A randomized controlled trial of preogressive resistance training in depressed elders. Journal of Gerontology, 52A(1), M27-M35.

Tanasescu, M., Leitzman, M.F., Rimm, E.B., and Hu, F.B. (2003). Physical activity in relation to cardiovascular disease and total mortality among men with type 2 diabetes. *Circulation*, 107, 2435-2439.

Thomas, K.S., Muir, K.R., Doherty, M., Jones, A.C., O'Reilly, S.C., & Bassey, E.J. (2002). Home based exercise program for knee pain and knee osteoarthritis: Randomised controlled trial. *British Medical Journal*, 325, 752-757.

Tsetsonis, N.V. & Hardman, A.E. (1994). The influence of the intensity of treadmill walking upon changes in lipid and lipoprotein variables in healthy adults. *European Journal of Applied Physiology*, 70, 329-336.

Tucker, L.A. & Silvester, L.J. (1996). Strength training and hypercholesterolemia: An epidemiologic study of 8499 employed men. *American Journal of Health Promotion,* 11(1), 35-41.

Tudor-Locke, C.E., Bell, R.C., & Myers, A.M. (2000). Revisiting the role of physical activity and exercise in the treatment of type 2 diabetes. *Canadian Journal of Applied Physiology*, 25(6), 466-491.

Walker, K.Z., Piers, L.S., Putt, R.S., Jones, J.A., & O'Dea, K. (1999). Effects of regular walking on cardiovascular risk factors and body composition in normoglycemic women and women with type 2 diabetes. *Diabetes Care*, 22(4), 555-561.

Whelton, S.P., Chin, A., Xin,X., & He, J. (2002). Effect of aerobic exercise on blood pressure: A meta-analysis of randomized, controlled trials. *Annals of Internal Medicine*, 136, 493-503.

Wing, R.R. (1999). Physical activity in the treatment of the adulthood overweight and obesity: Current evidence and research issues. *Medicine & Science in Sports & Exercise,* 31(11), S547-S559.

APPENDIX A-2

Agreement with Saskatchewan Ministry of Health,
Including approved technical description of data requirements

THIS Agreement made in duplicate:

BETWEEN:

University of Saskatchewan
Saskatoon, SK S7N 5E5
as represented by Dr. Karen Chad
(hereinafter called "the Researcher")

and

HER MAJESTY THE QUEEN in right of the Province of Saskatchewan as represented by the Minister of Health
(hereinafter called "the Province")

WHEREAS the Researcher wishes to conduct a study of physical activity, physical function and quality of life in older adults with chronic disease and the impact on health care costs in Saskatchewan, more fully described in Schedule A (hereinafter called "the Study")

AND WHEREAS the Province has in its custody and control certain personal health information that is required for the Study

AND WHEREAS the Researcher has obtained the express consent of the Study participants for the Province to disclose to the Researcher certain of their personal health services information

AND WHEREAS the Study has been approved by a research ethics committee approved by the Minister

AND WHEREAS the Province is prepared to provide that personal health information to the Researcher in accordance with the terms of this Agreement and *The Health Information Protection Act*;

NOW THEREFORE the parties agree as follows:

1.0 DEFINITIONS

1.1 For the purposes of this Agreement: "de-identified" means altering information so the identity of the person to whom it relates is removed and it cannot reasonably be expected to identify the person.

2.0 SERVICES

2.1 The Researcher has obtained the express written consent of each Study participant in relation to the personal health information the Researcher wishes to obtain from the

Province, a copy of which is attached as Schedule B to this Agreement. Copies of signed consent forms for each Study participant will be provided to the Province prior to the Province compiling the information required by this Agreement. The Province reserves the right to refuse to provide personal health information in relation to any Study participant if, in the sole opinion of the Province, the consent is not satisfactory.

2.2 The Province will for each Study participant for whom the Province has received a satisfactory written consent use the outpatient prescription drug, hospital services, physician services, and person registry files to compile information on health insurance coverage and service utilization from September 1, 2001 to June 30, 2008, as specified in Schedule C (the "dataset");

2.3 The Province will prepare an electronic copy of the dataset and provide one copy to the Researcher.

2.4 The Researcher acknowledges that health care provider information will be de-identified and not disclosed pursuant to this Agreement.

2.5 The Province will maintain the computer files created as a result of clauses 2.2 and 2.3 for a period not exceeding five years following delivery of the dataset.

3.0 PAYMENT FOR SERVICES

3.1 For the provision of services in accordance with this Agreement, the Researcher will pay to the Province:

(a) subject to clause 3.3, professional fees for Systems Consultant - $63 per hour for each full hour and a proportionate amount of that hourly fee for each part of an hour that the Systems Consultant spends in providing the services;
(b) system and network extraction charges, the sum of $4,315.00;
(c) all reasonable and direct expenses incurred in providing the goods and services in sub-clauses (a) or (b) or in administering this Agreement, including without limitation courier and long distance charges.

3.2 The Researcher agrees to pay all applicable taxes for the goods and services provided.

3.3 The hourly rate for the Systems Consultant (sub-clause 3.1(a)) is the current hourly rate charged to the Province by its Consultant. In the event the Consultant increases its hourly rate during the currency of this Agreement, the Researcher agrees to pay the Province in accordance with the new rate upon receiving written notice from the Province.

3.4 The fees and expenses referred to in clause 3.1 will be paid by the Researcher within 30 days after receiving an invoice from the Province setting out the number of days or hours, or proportion thereof, incurred during the invoice period and the expenses incurred.

3.5 In the event the total of amount invoiced for the goods and services exceeds $17,450.00, the Province shall suspend the provision of the services and notify the Researcher. The Province is relieved of its obligations under this Agreement until such time as the Researcher advises the Province to continue with provision of the services and agrees to pay the revised amount agreed upon by the Province and the Researcher. For greater certainty, this provision does not relieve the Researcher from paying all amounts properly owing up to $17,450.00.

4.0 CHANGES IN STUDY PROTOCOL

4.1 The Researcher shall advise the Province in writing of any modification requested to the dataset described more fully in Schedule C.

4.2 The Province shall review the changes requested to determine if the proposed changes are acceptable and deliverable.

4.3 If in the sole opinion of the Province the changes requested are acceptable and deliverable, the Province shall advise the Researcher of any increased costs associated with the changes and shall proceed with the changes only if the Researcher agrees to the increased costs.

4.4 Any agreed upon changes, including increased costs associated with the changes, will be in writing, signed by the parties and appended to this Agreement.

5.0 SUB-STUDIES AND FURTHER STUDIES

5.1 The Researcher agrees to use the dataset provided by the Province pursuant to this Agreement solely for the purpose of the Study, and shall not use or disclose the dataset for the purpose of any sub-study, secondary study or for any other purpose whatsoever.

5.2 Except for data or information obtained from each Study participant (as desribed in Schedule A) or as approved by the Province, the Researcher agrees not to compile, link or otherwise connect any of the dataset or any other information provided to the Researcher pursuant to this Agreement with any other individualized data or information accessible to the Researcher.

6.0 PUBLISHED REPORT

6.1 Subject to clause 10.2, the parties contemplate that the Researcher will prepare and publish one or more reports based on the Study. The Researcher agrees that any report based on the Study will not identify the Study participants to whom the dataset relates, whether the report is distributed or not. The Researcher shall provide the Province with final copies of all presented, distributed, and published reports.

7.0 DISCLAIMER

7.1 It shall not be inferred from the Province's provision of the dataset to the Researcher that the Province endorses the reports described in clause 6.1, and the following statement shall therefore be included prominently in each report:

> "This Study is based in part on data provided by the Saskatchewan Department of Health with the written consent of the beneficiary. The interpretation and conclusions contained herein do not necessarily represent

those of the Government of Saskatchewan or the Saskatchewan Department of Health."

8.0 REVIEW BY PROVINCE

8.1 The Researcher shall submit all reports described in clause 6.1 to the Province for review prior to presentation, distribution, or submission for publication for the purposes of identifying errors of methodology or interpretation and of ensuring that any references to the Province and its data are factually correct.

8.2 Article 8.0 shall survive the expiration or termination of this Agreement.

9.0 OWNERSHIP OF REPORT AND MATERIALS

9.1 The reports described in clause 6.1 will be the property of the Researcher and the Province is hereby granted a royalty-free right in perpetuity to reproduce and distribute the reports for its own purposes.

9.2 All other papers, information, data, software, programs and other materials produced by the Province in the performance of its obligations under this Agreement, including the dataset shall be and remain the property of the Province.

10.0 CONFIDENTIALITY

10.1 The Researcher agrees to comply with the following:
(a) protect and secure the dataset to ensure that it remains confidential and not disclose the same to any third party without the express authorization of the Province;
(b) keep the dataset separate and apart from other information and not combine the information with any other information, except as otherwise authorized by this Agreement;
(c) not, without prior written consent of the Province, process, store or transmit the dataset in a country other than Canada;
(d) not use the dataset for any purpose other the Study described in this Agreement;
(e) promptly return the dataset to the Province or destroy it in a manner approved by the Province and provide writtten confirmation to the Province that it has been so destroyed, when it is no longer required by the Researcher and in any event no later than five years after the termination or expiration of this Agreement.

10.2 The Researcher will make the dataset accessible only to those of its employees who require it to perform the Study and shall ensure that such empolyees are aware of and abide by the obligations of confidentiality under clause 10.1.

10.3 The Researcher will immediately advise the Province:
(a) if the Researcher knows or suspects that the dataset may have been compromised;
(b) if the Researcher or an affiliated company of the Researchers is served with an Order, demand, warrant or any other document purporting to compel the production of any of the dataset, including an order made pursuant to the Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terroroism (USA PATRIOT ACT);

(c) should the Researcher become aware that any requirement of this Article 10.0 has been breached.

10.4 The Researcher will indemnify and save harmless the Province from any actions, causes of action and liabilities of any form or kind arising out of or relating to the breach of any of the Researcher's obligations under this Article 10.0.

10. 5 The Researcher agrees to permit the Province to have access to the Researcher's premises, records and employees at any reasonable time, to perform any reviews and audits that the Province considers advisable to ensure that the Researcher is meeting the requirements of this Article 10.0 and the Researcher will provide its full co-operation for the purposes of such reviews or audits.

10.6 This section shall survicve the expiration or termination of this Agreement.

11.0 **TERM**

11.1 This Agreement comes in to force when signed by both parties and shall continue for a period of five years thereafter.

11.2 The term of this Agreement may be extended by the mutual agreement of the parties. The terms of this Agreement shall continue to apply during any period of extension unless otherwise agreed by the parties.

12.0 TERMINATION

12.1 Either party may terminate this Agreement at any time without cause by giving the other party thirty (30) days written notice of its intention to terminate.

12.2 If this Agreement is terminated prior to expiration by the Researcher, the Researcher shall pay to the Province the fees, costs and other expenses in accordance with clause 3.1 incurred prior to the termination.

13.0 NOTICES

13.1 All notices and communications to the Researcher in connection with this Agreement shall be addressed to:

University of Saskatchewan
Research Services
Box 5000, RPO University
110 Gymnasium Place
Saskatoon, SK S7N 4J8

and a copy to

Dr. K. Chad
Office of the Vice-President, Research
University of Saskatchewan
Room 201, College Building
107 Administration Place
Saskatoon, SK S7N 5A2 306-966-1615 (phone)

or to such other person as the Researcher may designate.

13.2 All notices and communications to the Province in connection with this Agreement shall be addressed to:

Mr. George Peters
Saskatchewan Health
3475 Albert Street
Regina, SK S4S 6X6 306-787-3629 (phone) 306-787-3112 (fax)

or to such other person as the Province may designate.

14.0 <u>MISCELLANEOUS</u>

14.1 The Researcher shall not assign this Agreement or any part thereof without the express written consent of the Province.

14.2 This Agreement enures to the benefit of and is binding on the parties' executors, administrators, successors and permitted assigns.

14.3 This Agreement shall be interpreted in accordance with the laws of Saskatchewan.

14.4 The marginal headings used in this Agreement are for convenience only and shall not be considered in its interpretation.

14.5 This Agreement and its Schedule shall constitute the entire agreement between the parties and supercedes all previous agreements relating to the services covered by this Agreement.

14.6 The Researcher shall comply with all applicable federal, provincial and municipal laws.

14.7 No delay, forbearance, or indulgence by any party in enforcing this Agreement shall constitute a waiver of any provision or obligation required to be performed or fulfilled under this Agreement.

SCHEDULE A

Title: Community Alliances for Health Research, Saskatoon ***in motion***: Are Community-based Physical Activity Programs Equivalent or Superior to Class-based (structured) Physical Activity Programs in Older Adults with Chronic Diseases.

It is well known that physical activity is very important in maintaining physical and mental health as well as quality of life as we get older. For individuals with chronic diseases such as diabetes, high blood pressure, high cholesterol, osteoporosis, arthritis and increased body weight, being physically active becomes even more important. Although diet and medications are often used for the treatment of such conditions, regular physical activity has been shown to have beneficial effects such as controlling blood sugar levels, decreasing high blood pressure and high cholesterol, reducing symptoms of arthritis, maintaining strong bones and promoting a healthy body weight.

Although the benefits of active living among those 50 years and older have been well established, physical activity levels among older age groups remain very low. Therefore, physical inactivity among older Canadians is a pressing national health problem. Because the amount of physical activity can be changed, there is a potential opportunity to increase the health and quality of life of older adults in Saskatoon.

We would like to ask for your assistance with a study that is being carried out by the University of Saskatchewan, Saskatoon District Health, the City of Saskatoon and ParticipACTION and funded by the Canadian Institutes of Health Research. The purpose of this study is to compare the impact of two types of physical activity programs: those carried out in the community versus those carried out in more structured exercise classes. There are no guaranteed benefits promised from your participation in this study, however, your participation in a physical activity program may have a beneficial effect on your health.

If you decide to volunteer for this study, your participation will consist of the following:

1. On four occasions (at baseline, 3 months, 6 months and 12 months) you will be asked to complete a health and lifestyle questionnaire and perform functional activity tests. Your heart rate, blood pressure, height, weight, waist and hip girths will be measured. To test your lower and upper body strength you will be asked to do arm curls and perform a sit-to-stand activity for 30 seconds. Some basic body movements and flexibility will be tested by measuring your arm reach while sitting and a back scratch activity. You will also be asked to walk for six minutes. You will be asked to perform nine simple functions related to activities of daily living including: writing, eating, lifting, dressing, bending, walking and turning. All of the testing will be carried out at the Saskatoon Field House. A trained fitness appraiser will review the questionnaires with you, answer any questions that you have and supervise the fitness tests. Each assessment will take approximately 1 hour. If you are diabetic, a graded exercise tolerance test with a medical doctor will be arranged prior to this assessment to exclude the possibility of heart disease.

2. Following completion of the initial assessment, you will be instructed and observed carrying out an activity program through two one-hour exercise assessment sessions. These sessions will involve aerobic activities such as walking and/or biking on a stationary bicycle, muscular strengthening activities with light free weights and light stretching activities. All exercise sessions will be held at the Saskatoon Field House.

3. Following the two exercise assessment sessions, you will be randomly assigned to attend either the First Step Program, a structured class-based program, or to an individual community-based program that will be arranged for you using existing programs elsewhere in Saskatoon. If you are assigned to the First Step Program, you will be encouraged to attend structured exercise classes at the Saskatoon Field House three times per week (Tuesday, Thursday morning or evening, Saturday morning) and attend the education sessions provided by the First Step Program. The cost of attending the First Step program is not covered by this research study. The activity program will include components of endurance (walking and/or stationary cycling and/or rowing and/or arm ergometer), strength (light free weights and/or tubing) and flexibility. You will be asked to complete a physical activity log to record the following: 1) physical activity type, frequency, duration and perceived exertion; 2) any injuries sustained; 3) details of participation in community-based physical activity programs and cost; and 4) purchase and cost of any fitness equipment for personal use. The program will continue for 3 months, after which time you will be provided with a list of community programs that are available for physical activity and be encouraged to continue your activity at these sites.

If you are assigned to a community-based program, a fitness appraiser will discuss with you the means to meet your activity goals through home-based physical activity and/or the use of community physical activity programs offered by community groups and facilities such as the City of Saskatoon, YWCA, YMCA and community associations. This activity program will consist of moderate intensity physical activity for 60 minutes at least three times per week that has a combination of endurance, strength and flexibility components. You will be encouraged to attend group education sessions at the Saskatoon Field House. Study research staff will contact you by telephone weekly for the first month, biweekly for the following two months, then monthly thereafter. You will be asked to complete a physical activity log to record the following: 1) physical activity type, frequency, duration and perceived exertion; 2) any injuries sustained; 3) details of participation in community-based physical activity programs and cost; and 4) purchase and cost of any fitness equipment for personal use. The cost of any programs you choose to participate in is not covered by this research project.

4. After 3, 6 and 12 months, you will be asked to return to the Saskatoon Field House at which time the same measurements taken at the start of the activity program will be repeated.

5. As this project is a partnership between the University of Saskatchewan and Saskatoon Health Region, we are interested in the effect that the physical activity program has had on your overall health. For a time period of one year prior to and five years following the start of your activity program your use of health services provided through Saskatchewan Health will be measured using the electronic provincial records. With your consent, Saskatchewan Health will provide the following information to the researchers:

- Demographic information such as date of birth and sex.
- Prescription drug history for the six-year period. This will include the date a prescription was filled, information on the drug provided, and the costs involved. This does not include any drugs you received in the hospital or that you purchased over the counter such as cold medicines or Aspirin.
- Information about physicians' visits within the six-year period including the date of a visit, the diagnosis, type of service provided (for example, annual physical examination), type of physician (eg. family doctor or a specialist) and the costs involved. This does not include the name of the physician or any doctor's notes.

- Information on any hospitalizations for the six-year period including the date you were admitted, when you were discharged, major procedures received (for example, bypass surgery), and why you were hospitalized (for example, appendicitis). This does not include any doctor's or nurse's comments or notes (or other clinical records).

Your health services number and use of services will remain confidential and your identity will not be associated with your number. Your information will remain anonymous, as results will be reported in published research as collective findings with no individuals identified.

All of the information provided through the questionnaires and activity logs will be kept confidential and stored by Dr. Karen Chad in a locked office on the University Campus when not in use, and for a minimum of five years after the completion of the study.

There may be unforeseen risks by your participation in a physical activity program. If you are diabetic, you may experience a low blood sugar that may cause a feeling of lightheadedness or dizziness. If you have high blood pressure, your blood pressure may rise or drop outside of healthy levels. Both blood pressure and blood sugar levels will be monitored during your initial assessment to identify such problems so they can be dealt with by your physician. During the testing, you may experience minimal fatigue and moderate exertion as you perform the physical tests. Some minor muscle discomfort one to two days following the testing may be experienced. You may also experience some minor muscle soreness and discomfort as a result of exercise that should decrease as the exercise program progresses.

You may be excluded from participation in this study if your assessments indicate that you may be unable to perform physical activity safely.

You will be advised if any new information or requirements arise that will have a bearing on your decision to continue in the study. You will be free to withdraw from any or all parts of the study at any time, without penalty. If you choose to withdraw from the study for any reason, there will be no repercussions for you in relation to your access to services through Saskatoon District Health, the City of Saskatoon, the University of Saskatchewan or any health care professionals. You may also choose to refuse participation in the study without affecting the quality of care you receive through Saskatoon District Health.

SCHEDULE B

Information for Participants
Saskatchewan Health Data & Health Service Utilization

Saskatchewan Health keeps some records about the health services you receive through the provincial health plan. As part of this study, we are interested in the effect that physical activity has had on your overall health and use of health services, like doctor visits and prescription drugs, and would like your consent to examine some of this information and use it for the study.

With your consent, Saskatchewan Health will provide the following information to the researchers for the time period of one year before and five years after the start of your participation in the study:

- Demographic information such as date of birth and sex.
- **Any** prescription drug history for the six-year period. This will include the date a prescription was filled, information on the drug provided, and the costs involved. This does not include any drugs you received in the hospital or that you purchased over the counter such as cold medicines or Aspirin.
- **Any** information about physician visits within the six-year period including the date of a visit, the diagnosis, type of service provided (for example, annual physical examination), type of physician (eg. family doctor or a specialist) and the costs involved. This does not include the name of the physician or any doctors' notes.
- **Any** information on any hospitalizations for the six-year period including the date you were admitted, when you were discharged, major procedures received (for example, bypass surgery), and why you were hospitalized (for example, appendicitis). This does not include any doctor's or nurse's comments or notes (or other clinical records).
- Your health services number will be used by Saskatchewan Health to get your records.

In addition, with your consent, Saskatoon Health Region will provide the following information to the researchers for the time period one year before and five years after the start of your activity program.

- Home care utilization data, such as the use of home care services, and the costs involved.

Your health services number and all health care information will remain confidential. Your information will remain anonymous, as results will be reported in published research as collective findings with no individuals identified. All of the information provided through questionnaires and activity logs, and all data information provided from Saskatchewan Health and Saskatoon Health Region will be kept will be kept confidential and stored by Dr. Karen Chad in a locked office on the University of Saskatchewan Campus when not in use, and for a minimum of five years after the completion of the study.

You will be free to withdraw from any or all parts of the study at any time, without penalty. Withdrawal from the study for any reason will in no way affect your present and future interactions with the University of Saskatchewan or your current or future medical care. If you would like to withdraw, or if you have any questions or concerns about this study, please do not hesitate to contact Dr. Karen Chad at any time:

Dr. Karen Chad, Principal Investigator, Saskatoon ***in motion***, College of Kinesiology, University of Saskatchewan, Saskatoon, Saskatchewan, S7N5C2, Phone: (306) 966-1071, Fax: (306) 966-6502, E-mail: chadk@duke.usask.ca

Participant's Statement of Consent

- I fully understand the contents of this consent form.
- I understand that my taking part is fully voluntary, and that I may decline to take part at any time without affecting my present and future interactions with the University of Saskatchewan or my current or future medical care.
- I understand that this information will be used for research purposes only and that any details that may reveal my identity will be excluded from study reports and presentations.
- I have received a copy of this consent form for my records.

Please circle your response in the two statements below.

I DO / DO NOT give permission for Saskatchewan Health to disclose my health care information as outlined above.

I DO / DO NOT give permission for Saskatoon Health Region to disclose my health care information as outlined above.

Participant Signature: ______________________ Date: __________

Saskatchewan Health Services # ________________

Investigator's Signature: ______________________ Date: __________

Dr. Karen Chad
Principal Investigator
Saskatoon ***in motion***

College of Kinesiology
University of Saskatchewan
Saskatoon, Saskatchewan, S7N 5C2
Phone: (306) 966-1071

SCHEDULE C

Physical activity, physical function and quality of life in older adults (50+) with chronic disease: The impact of health care costs

GENERAL FEATURES

1. Time Period: September 1, 2001 to June 30, 2008

2. Databases: person registry
   hospital separation
   physician services (including chiropractic & optometric)
   outpatient prescription drug

3. Age: 50+

4. Sex: male and female

5. Population: recruited study subjects (n=165)

OBJECTIVES

- To determine the level of physical activity, physical function and quality of life in individuals who participate in community and class-based programs.
- To determine the total cost per participant and the cost per unit of outcome (physical activity, physical function, quality of life) in community-based and class-based programs.
- To determine the use and cost of health services (e.g., physician services, hospitalisations, prescription drug services) by individuals in community-based and class-based programs.

STUDY OUTLINE

The Researchers will recruit the study subjects. The Researchers will provide Research Services with an electronic list of study subjects who have consented to the release of their personal health information and paper copies of their signed consent forms. The electronic list will be a fixed length flat ASCII file and will include the following variables: study identification number (assigned by the Researchers), health services number (HSN), sex, date of birth (yyyymmdd), and index date (enrolment date).

The **study index date** is the date of study enrolment. The **study entry date** is the later of index date minus 365 days or coverage initiation. The **study exit date** is the earliest of index date plus 1,826 days, death or coverage termination.

Information on hospital, physician, and outpatient prescription for up to one year prior to index and for up to five years following the index date will be compiled (i.e., between entry and exit dates).

Physician services information will be provided in two files: a visit file and a service file. Visits will be compiled by collapsing service records to a visit by the following variables: HSN, date, diagnosis, location of service, physician number, and clinic number. The service file will report information on fee-for-service codes (FSCs) of interest at the service record level.

Specific diagnostic codes (i.e., the actual ICD-9 or ICD-10-CA code to the fourth or sixth digit, respectively on the hospital file and the actual ICD-9 code to the third digit on the physician services file) will be reported for specified diagnoses only. All other diagnoses will be deleted or grouped. See Table 1.

Specific hospital procedure (CCP or CCI) codes and physician FSCs on the hospital services and physician services files respectively, will be reported for certain services only. All other procedure codes and FSCs will be deleted or grouped – see Table 2.

Drugs will be categorized at the Active Ingredient (AIN) level for drugs of interest only. All others will be grouped at a chemical or therapeutic group level – see Table 3.

DATA REQUIREMENTS

Subject File
Study ID number
study index date
study entry date
study exit date
sex
date of birth
death flag
registered Indian flag (0=never; 1=ever)

Prescription Drug File
Study ID number
drug category
dispensing date
government share of cost
total cost

Hospital File
Study ID number
Day surgery flag
admission date
discharge date
diagnosis (all available)
diagnosis type (all available)
procedures (all available)
date of procedure (all available)
external cause code (accident)
discharge type
intensity weight

Physician Visits File
Study ID number
date of visit
diagnosis

amount paid
physician type (1=gp; 2=specialist; 3=other/unknown)

Physician Services File
Study ID number
date of service
FSC
amount paid

Table 1: Diagnoses of Interest

Specific codes reported up to three digits on the physician services file and up to the fourth or sixth digit on the hospital services file; all other diagnostic codes will be suppressed

ICD-9 code	ICD-10-CA	Description
250.x	E10 - E14.xxx	diabetes mellitus
251.x	E15 E16.xxx	hypoglycemic coma other disorders of pancreatic internal secretion
272.x	E78.xxx	disorders of lipid metabolism
278.0^	E66.xxx	obesity
296.1^		manic-depressive psychosis, depressed type
296.3^		manic-depressive psychosis, circular type by currently depressed
300.4^		neurotic depression
308.x		acute reaction to stress
309.0^		brief depressive reaction
309.1^		prolonged depressive reaction
311	F32 - F33.xxx	depressive disorder, not elsewhere classified
350 - 359.x	G60 - G64.xxx	disorders of the perpipheral nervous system
362.0^	H36.0xx	diabetic retinopathy - this is an asterisk code; the associated ICD-9 and ICD-10-CA dagger codes are 250.4 and E10.3, E11.3, E12.3, E13.3, E14.3 respectively
401 - 405.x	I10 - I15.xxx	hypertension
410 - 414.x	I20 - I25.xxx	ischaemic heart disease
430 - 438.x	I60 - I69.xxx	cerebrovascular disease
390 - 400.x 406 - 409.x 415 - 429.x 439 - 459.x	I00 - I09.xxx I16 - I19.xxx I26 - I59.xxx I70 - I99.xxx	other diseases of the circulatory system
580 - 583.x 587 - 593.x	N25 - N29.xxx	other disorders of kidney and ureter
584 - 586.x	N17 - N19.xxx	renal failure
715.x	M15 - M19.xxx	osteoarthritis and allied disorders

	790.6^		other abnormal blood chemistry, including but not limited to hyperglycemia
Grouped diagnoses			
DG01	001 - 139.x	A00-B99.xxx U00.xxx	infectious and parasitic diseases
DG02	140 - 239.x	C00-D48.xxx	neoplasms
DG03	240 - 249.x 252 - 271.x 273 - 278 278.1- 279.x	E00 - E09.xxx E15 - E65.xxx E67 - E77.xxx E79 - E90.xxx	other endocrine, nutritional and metabolic diseases and immunity disorders
DG04	280 - 289	D50 - D89.xxx	diseases of blood and blood-forming organs
DG05	290 - 296.0 296.2 296.4 - 300.3 300.5 - 307.x 309 309.2 - 310.x 312 - 319.x	F00 - F31.xxx F34 - F99.xxx	other mental disorders
DG06	320 - 349.x 360 - 362 362.1 - 389.x	G00 - G59.xxx G65 - H36 H36.1 - H95.xxx	other diseases of the nervous system and sense organs
DG07	520 - 579	K00-K93.99	diseases of the digestive system
DG08	594 - 629.x	N00 - N16.xxx N20 - N24.xxx N30 - N99.xxx	other diseases of the genitourinary system
DG09	630 - 676	O00-O99.99	complications of pregnancy childbirth and the puerperium
DG10	680 - 709	L00-L99.99	diseases of the skin and subcutaneous tissue
DG11	710 - 714.x 716 - 739.x	M00 - M14.xxx M20 - M99.xxx	other diseases of the musculoskeletal system and connective tissue
DG12	740 - 779	P00-Q99.xxx	congential anomalies and certain conditions originating in the perinatal period
DG13	780 - 790.5 790.7 - 799.x	R00-R99.xxx	other symptoms, signs and ill-defined conditions
DG14	800 - 999	S00-T98.99	injury and poisoning
DG15^^	E000 - E999.x	V01 - Y98.xx U98 - U99.xxx	external causes of morbidity and mortality; place of occurrence; and activity

DG16	V01 - V82	Z00-Z99.99	supplementary classification of factors influencing health status and contact with health services
DG17		n/a	Medical Services Plan (MSP) assigned codes

^These codes are specific only if the fourth digit is reported. Therefore, they will not be reported on the physician services file because of insufficient specificity at the three-digit level.

^^ External cause codes are reported in a separate "accident" field prior to April 1, 2002. Therefore, no hospital separation records with a discharge date before April 1, 2002 can report this diagnostic category.

ICD-9: World Health Organization. Manual of the international statistical classification of diseases, injuries, and causes of death, 9th revision. Geneva: The Organization; 1977.

ICD-10-CA: International statistical classification of diseases and related health problems (ICD-10-CA) [monograph on CD-ROM]. 10th revision. Ottawa: Canadian Institute for Health Information; 2003.

Table 2: Procedure codes of interest
the following codes will be reported and all others will be suppressed

Description	physician	hospital	
	FSC	CCP	CCI
stimulation, brain	042E	08.38	1.AN.09.xx-xx-x
pharmacotherapy (local), vitreous	756S	28.7x	1.CM.35.xx-xx-x
excision total, vitreous	230S		1.CM.89.xx-xx-x
electrocardiogram or phonocardiogram	30D - 32D 141D - 142D	03.5x	
cardiac arrhythmia cardioversion	42D	13.7x	
exercise tolerance test	062D	03.4x	
stress echocardiography	65D - 66D		
dipyridamole thallium test	144D		
blood pressure monitoring	145D	03.69	
plasmapheresis - cell separation	150D - 151D	13.04	
destruction, retina	175S - 176S	28.5x	1.CN.59.xx-xx-x
bypass, dilation, extraction, pharmacotherapy of vessels other than arteries of the heart (i.e., other vascular surgery)	169L 174L 188L - 189L 191L 460L - 467L 474L 568L 668L 768L 790L - 791L	50.xx 51.1x 51.22 51.24 - 51.29 51.3x	1.JA.76.xx-xx-x 1.IB.76.xx-xx-x 1.IC.76.xx-xx-x 1.ID.76.xx-xx-x 1.IL.35.xx-xx-x 1.JE.76.xx-xx-x 1.JM.76.xx-xx-x 1.JJ.76.xx-xx-x 1.JK.76.xx-xx-x 1.KA.76.xx-xx-x 1.KE.50.xx-xx-x 1.KE.35.xx-xx-x 1.KE.57.xx-xx-x 1.KE.76.xx-xx-x 1.KE.87.xx-xx-x 1.KG.76.xx-xx-x 1.KR.58.xx-xx-x 1.KR.76.xx-xx-x 1.KY.76.LA 1.KY.76.LA

PTCA (i.e., angioplasty of coronary arteries)	303A 328A - 329A 335A 443A 447A 545A 548A	48.0x	1.IJ.50.GQ-BD-x 1.IJ.50.GQ-BF-x 1.IJ.50.GQ-OA.x
extraction coronary arteries			1.IJ.57.xx-xx-x
aorto-coronary bypass w tissue stabilizing device	138L		
coronary pathy angioplasty greater than 3 cm in ength	755L		
intra-aortic balloon pump placement	130L - 132L	49.61	
CABG	123L 153L - 155L 161L 654L - 655L	48.1x 48.2x	1.IJ.76.xx-xx-x
implantation of internal device, vena cava	458L	50.6x	1.IS.5 xx-xx-
installation of external appliance, circulatory system NEC			1.LZ.37.xx-xx-x
renal dialysis	117D - 119D 121D -124D 128D - 132D 660L - 663L 666L - 667L 669L - 671L 648X	51.95 66.98	1.PZ.21.xx-xx-x 1.OT.53.xx-xx-x 1.OT.54.xx-xx-x 1.KY.76.LA-SJ-x 1.SY.55.LA-FT-x 7.SC.59.QD-xx-x
implantation, pelvis			1.SQ.53.xx-xx-x
total hip replacement	435M 445M 845M	93.5 - 93.6x	1.VA.53.xx-xx-x
amputation, lower extremity	763M 765M - 766M 768M 772M 774M	96.1x	1.VC.93.xx-xx-x 1.VG.93.xx-xx-x 1.VQ.93.xx-xx-x 1.WA.93.xx-xx-x 1.WE.93.xx-xx-x 1.WJ.93.xx-xx-x 1.WL.93.xx-xx-x 1.WM.93.xx-xx-x

total knee replacement	436M 444M	93.41	1.VG.53-xx-xx-x
other procedures on the lower extremities including transfer, excision, immobilization, fixation, repair, fusion, implantation, reduction, and inspection of foot, toes, anke, patella, femur, knee, tibia, fibula, etc.	359M	89.04 - 89.08 89.14 - 89.18 89.24 - 89.28 89.34 - 89.38 89.4x 89.54 - 89.58 89.64 - 89.68 89.74 - 89.78 89.84 - 89.88 89.94 - 89.98 90.04 - 90.08 90.14 - 90.18 90.24 - 90.28 90.34 - 90.38 90.44 - 90.48 90.54 - 90.58 90.64 - 90.68 90.74 - 90.78 90.84 - 90.88 90.94 - 90.98 91.04 - 91.08 91.14 - 91.18 91.24 - 91.28 91.34 - 91.38 91.44 - 91.48 91.54 - 91.58 91.64 - 91.68 91.7 - 91.8x 91.94 - 91.98 92.04 - 92.08 92.14 - 92.18 92.24 - 92.28 92.34 - 92.38 92.44 - 92.48 92.54 - 92.58 92.64 - 92.68 92.74 - 92.78 92.84 - 92.88 92.94 - 92.98 93.0 - 93.6x 93.9x	1.VC.83.xx-xx-x 1.VC.91.xx-xx-x 1.VG.03-xx-xx-x 1.VG.73.xx-xx-x 1.VG.74.xx-xx-x 1.VG.87.xx-xx-x 1.VP.53.xx-xx-x 1.VP.80.xx-xx-x 1.VQ.83.xx-xx-x 1.VQ.91.xx-xx-x 1.VS.80.xx-xx-x 1.WA.75.xx-xx-x 1.WE.75.xx-xx-x 1.WE.80.xx-xx-x 1.WE.87.xx-xx-x 1.WE.73.xx-xx-x 1.WJ.73.xx-xx-x 1.WJ.75.xx-xx-x 1.WJ.80.xx-xx-x 1.WJ.87.xx-xx-x 1.WM.73.xx-xx-x 1.WM.75.xx-xx-x 1.WM.80.xx-xx-x 1.WM.87.xx-xx-x 2.VG.70.xx-xx-x
hyperthermy, total body		07.35	1.ZZ.07.xx-xx-x
Pharmacotherapy, total body			1.ZZ.35-xx-xx-x

x-ray, vascular	307X 330X - 334X 501X 504X^ 600X 604X^	50.8 50.82 80.84 - 50.89 48.98	3.ID.10.xx-xx-x 3.IP.10.xx-xx-x 3.JE.10.xx-xx-x 3.JG.10.xx-xx-x 3.JL.10.xx-xx-x 3.JM.10.xx-xx-x 3.JW.10.xx-xx-x 3.JX.10-xx-xx-x 3.JY.10.xx-xx-x 3.KC.10.xx-xx-x 3.KE.10.xx-xx-x 3.KG.10.xx-xx-x 3.KT.10-xx-xx-x
x-ray, ophthalmic angiography	040S - 041S 426S - 427S	09.12	3.JS.10.xx-xx-x
MRI thoracic vessels NEC			3.JY.40.xx-xx-x
u/sound - echocardiography	20W	02.82	3.IP.30.xx-xx-x
u/sound - sonography abdoment	30W - 31W	02.86	
u/sound vascular - peripheral arterial	750L - 752L	02.87	
x-ray, gi tract NEC		02.3x	3.NZ.10.xx-xx-x
x-ray abdominal cavity		02.5x	3.OT.10.xx-xx-x
therapy, mental health psychiatry	31E 33E - 35E 37E - 39E 40E - 42E	08.43 - 08.46 08.48 - 08.49	6.AA.30.xx-xx-x 6.DA.30.xx-xx-x
therapy, congition and learning			6.KA.30-xx-xx-x
other heart revascularization		48.3x	
other operations on vessels of heart		48.9x	

CCP: Canadian Classification of Diagnostic, Therapeutic and Surgical Procedures. Statistics Canada, 1986.

CCI: Canadian Classification of Health Interventions. CIHI, 2001.

Hospital services records with a discharge date up to and including March 31, 2002 are coded with CCP. Hospital services records with a discharge date of April 1, 2002 or later are coded with CCI.

^These FSCs are used by radiologists for angiography and angioplasty of vessels other than heart vessels.

Table 3: Drugs of Interest

The following categories will be reported

Category	Description		
1	ACE inhibitors:		
	benazepril	enalapril/HCTZ	perindopril/indapamide
	captopril	fosinopril	quinapril
	cilazapril	lisinopril	quinapril/HCTZ
	cilazapril/HCTZ	lisinopril/HCTZ	ramipril
	enalapril	perindopril	trandolapril
2	ARBs:		
	candesartan	irbesartan	telmisartan
	candesartan/HCTZ	irbesartan/HCTZ	telmisartan/HCTZ
	eprosartan	losartan	valsartan
	eprosartan/HCTZ	losartan/HCTZ	valsartan/HCTZ
3	CCB - dihydropyridine (typically used to treat HT)		
	amlodipine	nicardipine	
	felodipine	nifedipine long-acting	
4	CCB - nonDHP (typically used to treat HT)		
	diltiazem long acting		
	verapamil		
5	CCB - dihydropyridine (typically not used to treat HT)		
	nifedipine regular		
6	CCB - nonDHP (typically not used to treat HT)		
	diltiazem regular		
7	alpha blockers:		
	clonidine	prazosin	
	doxazosin	terazosin	
8	beta blockers (nonselective)		
	labetolol	pindolol/HCTZ	timolol/HCTZ
	nadolol	propranolol	
	oxprenolol	propranolol/HCTZ	
	pindolol	timolol	
9	beta blockers (beta1 selective)		
	acebutolol	atenolol/chlorthalidone	
	atenolol	metoprolol	
10	centrally acting a/hypertensives:		
	debrisoquine	methyldopa/CTZ	reserpine
	guanethidine	methyldopa/HCTZ	reserpine/chlorthalidone
	hydralazine	minoxidil	reserpine/hydralazine/HCTZ
	methyldopa		

11	combination diuretics amiloride/HCTZ spironolactone/HCTZ triamterene/HCTZ		
12	nitrates: erythrityl tetranitrate isosorbide dinitrate	 isosorbide-5-mononitrate nitroglycerin	
13	anti-arrhythmics: amiodarone disopyramide flecainide	 mexiletine procainamide propafenone	 quinidine sotalol tocainide
14	digitalis glycosides: digoxin		
15	beta-blockers used for CHF bisoprolol (EDS) carvedilol (EDS)		
16	vasodilators: dipyridamole (EDS) dipyridamole/ASA (EDS)	 nimodipine (EDS)	
17	platelet inhibitors: clopidogrel (EDS) pentoxifylline	 sulfinpyrazone ticlopidine (EDS)	
18	anticoagulants: acenocoumarol dalteparin (EDS) enoxaparin (EDS)	 heparin nadroparin (EDS) tinzaparin (EDS)	 warfarin
19	statins: atorvastatin cerivastatin fluvastatin	 lovastatin pravastatin rosuvastatin	 simvastatin
20	fibrates: bezafibrate (EDS) clofibrate fenofibrate (EDS)	 gemfibrozil	
21	bile acid sequestrants: cholestyramine colestipol		
22	other lipid lowering agents: ezetimibe niacin 500 mg	 probucol	

23	oral hypoglycemics:		
	acarbose	metformin	rosiglitazone (EDS)
	chlorpropamide	nateglinide (EDS)	rosiglitazone/metformin (EDS)
	gliclizide	pioglitazone (EDS)	tolbutamide
	glyburide	repaglinide (EDS)	
24	insulin		
25	diabetes testing agents		
26	diabetes supplies		
27	NSAIDs:		
	ASA	ibuprofen	naproxen
	celecoxib	indomethacin	phenylbutazone
	diclofenac	ketoprofen	piroxicam
	diclofenac/misoprostol	mefenamic acid	rofecoxib
	diflunisal	meloxicam	sulindac
	etodolac	nabumetone	tiaprofenic acid
	flurbiprofen		
28	SSRIs		
	citalopram	fluvoxamine	sertraline
	fluoxetine	paroxetine	
29	TCAs:		
	amitriptyline	desipramine	nortriptyline
	amitriptyline/perphenazine	doxepin	protriptyline
	amoxapine	imipramine	trimipramine
	clomipramine	maprotiline	
30	MAOIs:		
	isocarboxacid	tranylcypromine	
	phenelzine	moclobemide (type A)	
31	other a/depressants:		
	bupropion	mirtazapine	trazodone
	nefazodone	nomifensine	venlafaxine
32	diuretics		
	chlorthalidone	indapamide	
	hydrochlorothiazide (HCTZ	metolazone	
33	loop diuretics		
	bemetanide	furosemide	
	ethacrynic acid		
34	potassium-sparing diuretic		
	amiloride	triamterene	
	spironolactone		
38	all others		

EDS drugs are listed in the Saskatchewan Formulary with restricted coverage. Physicians or pharmacists must apply to the Drug Plan for approval for individual patient coverage under the Exception Drug Status (EDS) program. If an application is not approved or an EDS application is not made, the use of these agents is not captured in the database. Historical coverage criteria for individual agents are available upon request. Current coverage criteria for individual agents are available online at: http://formulary.drugplan.health.gov.sk.ca.

APPENDIX B-1

Application for access to the Saskatchewan Research Data Centre (SKY-RDC)

1. Project Title:

Physical Activity and Health Services Utilization among Canadian Older Adults

2. Study Rationale and Objectives:

The benefits of physical activity in reducing the morbidity and mortality associated chronic conditions such as obesity, type 2 diabetes mellitus (T2DM), coronary heart disease, stroke, osteoporosis and certain types of cancer have been well established (Warburton et al., 2006; Warburton et al., 2007). In addition to being associated with physical inactivity, most of the above listed conditions are also associated with increasing age. There is considerable literature demonstrating that functional limitations resulting from age-related disease or disabilities may be attenuated or reversed by a physically active lifestyle, even though the impairment is not eliminated (Singh, 2002). Although the importance of being physically active is widely acknowledged among the Canadian population, levels of physical activity remain low, particularly among older adults. Recent data suggests that 62% of Canadian adults aged 65 and older (67% of women, 55% of men) are physically inactive (NACA 2006).

At a global level, physical inactivity imposes a significant economic and societal burden. It is estimated that 2 million premature deaths each year can be attributed to physical inactivity, including roughly one quarter of cases of CHD and approximately 15% of cases of T2DM, breast, colon and rectal cancer worldwide (WHO, 2002). Nationally, physical inactivity accounted for 2.6% ($5.3 billion) of the total healthcare costs in Canada in 2001 (Katzmarzyk & Janssen, 2004). It has been estimated that just a 10% reduction in physical inactivity could potentially reduce direct health care expenditures by $150 million dollars per year, underscoring the importance of public health strategies aimed at increasing physical activity levels (Katzmarzyk et al 2000).

Canadian society is aging such that by 2026, it is expected that 20% of the population will be aged 65 years or older (Health Canada, 2002). With increasing age, the prevalence of most chronic diseases increases as does the possibility of impairment and disability associated with functional decline. As a result, our health care system will likely face tremendous pressure in the coming years particularly since the average life expectancy at 65 years of age is 21.0 years for women and 17.7 years for men (OECD, 2007). Given that individuals who reach this age in relatively good health have a quarter or more of their life remaining, it would seem that increasing physical activity levels among older adults could play a significant role in reducing health services utilization and costs. However, there has been relatively little research in this area and the majority of studies have been based on data from the HMO and Medicare systems in the United States. In fact, a recent review of trends in physical activity research suggests that just 2% of all physical activity research in Canada is health services related (Herman et al 2007).

In reviewing the literature concerning physical activity and health services utilization, three Canadian studies were identified. Dunlop et al (2000) examined the factors associated with the use of physician services using data from the 1994 National Population Health Survey and found that physical inactivity was not significantly associated with visits to a general practitioner but was significantly associated with specialist visits. Specifically, females reporting physical inactivity were significantly more likely to visit a specialist 6 or more times than those reporting physical activity. However, among males this association was not statistically significant suggesting that perhaps the relationship between physical activity and health service utilization is not as straightforward as one might think (Dunlop et al 2000). In two frequently cited studies of the economic burden of physical inactivity, Katzmarzyk and colleagues determined that approximately 2.5% - 2.6% of the direct health care costs in Canada were attributable to physical inactivity in 1999 and 2001, respectively based upon relative risk estimates for each condition and the prevalence of physical inactivity in Canada (Katzmarzyk et al 2000; Katzmarzyk & Janssen, 2004). These estimates are compelling but do not provide insight into where and how these costs are incurred, an important consideration in health policy and resource management. Given the lack of Canadian-based research in this area, further understanding of the relationship between physical activity and health service utilization is necessary in order to develop an evidence base on which researchers, health providers, policy makers and organizations can support decisions regarding funding of programs such as physical activity interventions.

Research Objectives

The purpose of the proposed study is to examine the relationship between physical activity and health services utilization in older Canadians. This study will address two principal questions:

a. Is the level of health services used by physically active older adults significantly different from the level of health services used by physically inactive older adults?
b. What factors influence the level of health services utilization of physically active and physically inactive older adults in Canada?

3. Proposed data analysis and software requirements

The proposed data analysis will be carried out using SPSS Version 15.0. In order to be able to make inferences to the Canadian population aged 50 years and older, sampling weights will be applied in all analyses. Unweighted results will not be removed from the RDC. To account for the multi-stage sample design of the surveys, bootstrap procedures will be used to calculate confidence intervals and coefficients of variation, and to test the statistical significance of differences. A significance level of $p < 0.05$ will be applied in all cases.

In order to describe the characteristics of the study population, frequencies or means ± SD will be determined as appropriate for all independent variables of interest. The sample will be stratified on the basis of age and physical activity level into three age groups (50 – 64 years, 65 – 79 years, 80 years and older) and two activity levels (active and inactive). The distribution of independent variables between groups will be compared using chi square and ANOVA for categorical and continuous variables, respectively.

For the purposes of this study, health services utilization will be operationalized through four outcome variables:

a. # of consultations with family doctor
b. # of consultations with other medical doctor
c. # of consultations with other health care professionals
d. Incidence of overnight hospitalization
e. # of nights spent in hospital

Question 1:

Each of the first four outcome variables listed above will be compared for active and inactive older adults in three age groups using two way ANOVA and chi square, as appropriate. Two way ANOVA will be used to compare the number of nights spent in hospital between active and inactive older adults for those reporting being hospitalized in the last year.

Question 2:

Since the factors that influence the use of health services may differ according to the type of provider, each outcome variable will be assessed separately. Negative binomial regression analyses will be used to assess outcome variables based on count data (variables a – c, e) due to the substantial over-dispersion characteristic of such data. Logistic regression analysis will be used to model the factors associated with the overnight hospitalization (variable d).

4. Data Requirements

In order to undertake the proposed research, access to the confidential Master Data File for Cycle 3.1 of the Canadian Community Health Survey (CCHS) is requested. The CCHS includes nationally representative data related to health determinants, health status and health care utilization for the Canadian population and therefore, is an appropriate data source for the proposed research.

Access to the CCHS 3.1 confidential Master Data File is requested for two important reasons. First, in order to carry out the proposed analytical plan, bootstrap procedures will need to be used in order to compute precise coefficients of variation and these require information that is available only through the confidential Master Data File. Secondly, the Public Use Microdata File (PUMF) excludes the Urban/Rural Classification (GEOnDUR2) variable. This variable is an indicator of access to health services which is an important potential moderator of health services utilization. Therefore, including this variable in the proposed analysis will strengthen the methodology substantially and further inform the interpretation of the findings.

Population of Interest

The population of interest in the proposed study includes CCHS 3.1 respondents aged 50 years of age and older (N=58 323).

Variables

The decision to seek out and utilize health services is commonly described and studied using Anderson and Newman's behavioural model of health services utilization. In this framework, the volume of health services used by an individual is determined by three factors – one's predisposition to use health services, one's ability to access services and how sick an individual is. Predisposing factors are present before the illness begins and they explain in part why some people use services more than others; enabling factors are characteristics that may facilitate or impede one's ability to obtain health services; and need factors relate to a person's current perceived and/or actual health status. Poor health is the most immediate predictor for health care utilization.

The following variables of interest are to be used in the proposed study based upon their role as predisposing, enabling or need determinants of health services utilization and their potential contribution to the outcome variables. All variables of interest are available in the CCHS 3.1 main file.

Dependent (Outcome) Variables	
HCUE_1AA	Has regular medical doctor
HCUEG02A	# of Consultations with Family doctor
HCUEG02C	# of Consultations with other Medical Doctor
HCUEGMDC	# of Consultations with Medical Doctor (grouped)
HCUEFCOP	Consultations with other health professionals in last 12 months – (flag)
HCUEG02D	Number of consultations - nurse – (grouped)
HCUEG02E	Number of consultations – dentist or orthodontist – (grouped)
HCUEG02F	Number of consultations – chiropractor – (grouped)
HCUEG02G	Number of consultations – physiotherapist – (grouped)
HCUEG02H	Number of consultations – social worker/counselor – (grouped)
HCUEG02I	Number of consultations – psychologist – (grouped)
HCUEG02J	Number of consultations – speech/audiology/occup therapist – (grouped)
HCUE_01	Overnight patient in hospital in last year
HCUEG01A	Number of nights as patient
HCUE_04	Consulted alternative health care provider – (flag)
HMCEFRHC	Received home care - (flag)

Independent Variables of Interest	
PACEDEE	Daily Energy Expenditure
PACEDPAI	Physical Activity Index
PACEFLEI	Participant in Leisure time physical activity – (flag)

Independent Variables of Importance			
DHHEGAGE	Age – Grouped		
DHHE_SEX	Sex		
GEOEGPRV	Province of Residence		
GEOnDUR2	Urban-Rural Classification – Grouped		
DHHEGMS	Marital Status		
INCEGHH	Total Household Income – All Sources		
EDUEDR04	Highest Level of Education – Respondent, 4 Levels		
GENEDHDI	Self-rated Health		
GENEDMHI	Self-rated Mental Health		
HWTEGBMI	Body Mass Index – self-reported (grouped)		
HWTEGISW	BMI classification (self-reported) – international standard – (grouped)		
CCCEF1	Has at least one chronic condition		
CCCE_011	Food allergies	CCCE_161	Urinary incontinence
CCCE_021	Other Allergies	CCCE_171	Bowel disorder
CCCE_031	Asthma	CCCE_191	Cataracts
CCCE_041	Fibromyalgia	CCCE_201	Glaucoma
CCCE_051	Arthritis/rheumatism	CCCE_211	Thyroid condition
CCCE_061	Back problems (excl 041, 051)	CCCE_251	Chronic Fatigue Syndrome

CCCE_071	High Blood Pressure	CCCE_261	Mult. Chemical Sensitivities
CCCE_101	Diabetes	CCCE_280	Mood disorder
CCCE_111	Epilepsy	CCCE_290	Anxiety Disorder
CCCE_121	Heart Disease	CCCE_91A	Chronic Bronchitis
CCCE_131	Cancer	CCCE_91E	Emphysema
CCCE_141	Stomach/Intestinal Ulcers	CCCE_91F	COPD
CCCE_151	Effects of Stroke		
ALCEDTYP	Type of Alcohol User		
SMKEDSTY	Type of Smoker		
INJE_01	Injury in last 12 months		
INJE_13	Most serious injury - medical attention within 48 hrs		
INJE_16	Other injuries – sought attention from health professional		
INJEDSTT	Injury status		
RACEDPAL	Participation and Activity Limitation		

5. Expected project start and end dates

This project is expected to start April 15, 2008 and continue until March 31, 2009.

6. Expected Products

It is expected that this project will result in the following products:

a. one study within a Ph.D. dissertation
b. at least one peer-reviewed journal article.

11. References

Dunlop, S., Coyte, P.C., & McIsaac, W. (2000) Socio-economic status and the utilisation of physicians' services: results from the Canadian National Population Health Survey. *Social Science and Medicine, 51*: 123-133.

Herman, K.M., Ardern, C.I., Mason, C., Brien, S.E., & Katzmarzyk, P.T. (2007). Trends in physical activity research in Canada. *Applied Physiology, Nutrition and Metabolism, 32(3)*: 400-408.

Katzmarzyk, P.T., Gledhill, N.,& Shephard, R.J. (2000). The economic burden of physical inactivity in Canada. *Canadian Medical Association Journal, 163(11)*: 1435-1440.

Katzmarzyk, P.T. & Janssen, I. (2004). The economic costs associated with physical inactivity and obesity in Canada: an update. *Applied Physiology, Nutrition and Metabolism, 29(1)*: 90–115.

Health Canada (2002). Canada's Aging Population (Cat. No. H39-608/2002E). Ministry of Public Works and Government Services, Ottawa, ON.

NACA. (2006). *Seniors in Canada 2006 Report Card* (Cat. No. HP30-1/2006E). National Advisory Council on Aging (NACA), Ottawa, ON.

OECD. (2007). OECD *Health Data 2007, October 07*. Retrieved March 1, 2008, from http://www.oecd.org/document/60/0,2340,en_2825_495642_2085200_1_1_1_1,00.html

Singh, M.A. (2002). Exercise to prevent and treat disability. *Clinics in Geriatric Medicine, 18*: 431-462.

Warburton, D.E., Nicol, C., & Bredin, S.S. (2006). Health benefits of physical activity: the evidence. *Canadian Medical Association Journal, 174*: 801-809.

Warburton, D.E.R., Katzmarzyk, P.T., Rhodes, R.T., & Shephard, R.J. (2007). Evidence-informed physical activity guidelines for Canadian adults. *Canadian Journal of Public Health, 98 (Suppl 2)*: S16-S68.

World Health Organization. (2004). *Global strategy on diet, physical activity and health – physical activity fact sheet.* Retrieved March 1, 2008 from http://www.who.int/dietphysicalactivity/media/en/gsfs_pa.pdf

APPENDIX B-2

SSHRC Letter of Approval for access to SKY-RDC

Social Sciences and Humanities Research Council of Canada
Conseil de recherches en sciences humaines du Canada

April 1, 2008
File: CISS-RDC-Fisher/ 353920

Ms. Koren Fisher
University of Saskatchewan
College of Kinesiology
87 Campus Drive
Saskatoon, SK S7N 5B2

Dear Ms. Fisher:

Thank you for submitting an application to the *CISS-Access to the RDC Program*, a joint initiative between Statistics Canada, the Social Sciences and Humanities Research Council and the Canadian Institutes of Health Research. The RDC-Access Granting Committee has now completed the review of your proposal and has approved it. We will now notify Statistics Canada so that it can do the required security check.

We also ask that you contact the RDC analyst and make an appointment to begin the administrative processes to gain access to the centre. Your centre can be found at the following website: http://www.statcan.ca/english/rdc/network.htm

Each proposal was evaluated on the basis of four main criteria: scientific merit and viability of the proposed research; the viability of the methods to be applied given the data on which the analysis will be performed; a demonstrated need for access to detailed micro data; and, the expertise and ability of the researchers to carry out the work.

Your approved access to an RDC for the purposes of this research project will expire after 6 months from the date of this letter; whereupon you will need to re-apply to SSHRC in order to re-gain access to the RDC. If you are unable to commence your research project within this 6-month time frame, please contact the RDC analyst to make special arrangements.

You will find enclosed an evaluation submitted to SSHRC by the RDC-Access Granting Committee. Should you have further questions, please feel free to contact the officer responsible for the administration of the *CISS-Access to the RDC Program*, Mika Oehling, at (613) 992-4227 or by email at rdc@sshrc.ca.

Yours sincerely,

Murielle Gagnon
Director
Strategic Programs and Joint Initiatives

c. c. Beverley Hunt
Research Data Centres Headquarters Operations

encl.

350 ALBERT STREET
PO BOX 1610 STN B
OTTAWA ON K1P 6G4
www.sshrc.ca

350, RUE ALBERT
CP 1610 SUCC B
OTTAWA ON K1P 6G4
www.crsh.ca

APPENDIX B-3

Description of control variables included in analyses in Study 1

Table B.1 Description of control variables included in analyses in Study 1

	CCHS Questionnaire Item	**CCHS Variable Coding**	**Final Variable Coding**
Predisposing Factors			
Age	What is your age in years?	Continuous variable	
Gender		Male Female	*Male* Female
Marital Status	Respondent's marital status	• Now married • Common-law • Widowed • Separated • Divorced • Single/Never married	• Married (Married, Common law) *Yes* / No
Education	Highest level of education acquired by respondent	• <Secondary school graduation • Secondary school graduation; no post secondary • Some post-secondary education • Post-secondary degree/diploma	• Completed secondary school or higher *Yes* / No
Ethnicity	Cultural or racial background	White only; Black only; Korean only; Filipino only; Japanese only; Chinese only; South Asian only; Southeast Asian only; Arab only; West Asian only; Latin American only; Other racial/cultural origin; Multiple racial/cultural origins; Aboriginal	• Aboriginal Yes / *No*
Immigration	Indicates whether or not respondent immigrated to Canada and the length of time since immigration	Immigrant status • Yes • No Years since immigration • Continuous variable •	• Immigrant Yes / *No*

Table B.1 continued

Variable	CCHS Questionnaire Item	CCHS Variable Coding	Final Variable Coding
Enabling Factors			
Household Income	Best estimate of total annual household income before taxes and deductions	Continuous	• *< $15,000* • $15,000 - $29,999 • ≥ $30,000 • Missing
Employment Status	Indicates if respondent works full-time or part-time.	• Full Time • Part Time • Population exclusion − ≥75 years of age − Did not work in previous 12 months	• *Not employed (6)* • Employed (1,2)
Speaks English and/or French	Indicates language in which respondent can converse	• English • French • Both English & French • Neither English or French	• *Yes* • No
Has regular doctor	Indicates if respondent has a regular doctor?	• Yes • No	• *Yes* • No
Household Size	# of persons in household	Continuous	• *1 person* • 2 people • 3 or more people
Dwelling Size	# of bedrooms in dwelling	Continuous	• *< 3 bedrooms* • 3 bedrooms • >3 bedrooms

* Reference category is *italicized*

Table B.1 continued

Variable	CCHS Questionnaire Item	CCHS Variable Coding	Final Variable Coding
Need factors			
Self-rated general health	Respondent's health status based on his/her own judgement	• poor • fair • good • very good • excellent	• *excellent/very good/ good* • fair/poor
Self-rated mental health	Respondent's mental health status based on his/her own judgement	• poor • fair • good • very good • excellent	• *excellent/very good/ good* • fair/poor
Injury Status	Indicates if respondent had an activity limiting injury or an injury requiring treatment in previous 12 months	• No injuries • Activity-limiting (untreated) • Non-limiting (treated) • Activity limiting (treated)	• *No* • Yes
Limitations in ADLs	(Frequency of) activity limitation imposed by long term physical/mental health problem that has lasted/is expected to last ≥ 6 months	• Sometimes • Often • Never	• *Activity Limitations* Yes / *No*
Number of chronic conditions	Indicates level of co-morbidity		• *No conditions* • 1 condition • 2 conditions • 3 conditions or more conditions • ≥ 4 conditions

* Reference category is *italicized*

Table B.1 continued

Variable	CCHS Questionnaire Item	CCHS Variable Coding	Final Variable Coding
Need factors cont'd			
Chronic Conditions	Indicates if respondent has one or more chronic health conditions which were diagnosed by a health professional and affected their health for 6 months or longer. Food allergies, other allergies, asthma, fibromyalgia, arthritis/rheumatism, back problems, hypertension, migraines, emphysema, COPD, diabetes, epilepsy, heart disease, cancer, ever diagnosed with cancer, intestinal/stomach ulcers, effects of a stroke, urinary incontinence, Crohn's disease/ulcerative colitis/ irritable bowel syndrome/bowel incontinence, Alzheimer's disease/other dementia, cataracts, glaucoma, thyroid condition, chronic fatigue syndrome, multiple chemical sensitivities, schizophrenia, mood disorder, anxiety disorder, autism or other developmental disorder, learning disability, eating disorder, other long term physical or mental health condition	For each condition: • Yes • No	Conditions regrouped as follows: − Cardio/Cerebrovascular: heart disease, stroke − Hypertension − COPD: emphysema, chronic bronchitis, COPD − Asthma − Diabetes − Cancer: currently have/ever had cancer − Neurological conditions: chronic fatigue syndrome, migraines, Alzheimer's/other dementia, epilepsy − Rheumatological conditions: fibromyalgia, arthritis/rheumatism − Back Problems − Gastro-intestinal conditions: intestinal/stomach ulcers, Chrohn's disease/ulcerative colitis/irritable bowel syndrome/bowel incontinence − Mood/Anxiety Disorders − Other mental health conditions: schizophrenia, autism/other developmental disorder, eating disorder − Conditions not otherwise listed • *No* • Yes
BMI Classification	Classification of BMI (calculated based on self-reported height and weight) according to WHO standards	• Underweight (BMI<18.50) • Normal weight (BMI=18.50 – 24.99) • Overweight (BMI=25.00-29.99) • Class I Obesity (BMI=30.00-34.99) • Class II Obesity (BMI=35.00-39.99) • Class III Obesity (BMI>40.00)	• *BMI < 25.0 kg·m^{2})* • BMI=25.0 -29.99 kg·m^{2}) • BMI ≥30.0 kg·m^{-2})

* Reference category is *italicized*

Table B.1 continued

Variable	CCHS Questionnaire Item	CCHS Variable Coding	Final Variable Coding
Personal Health Practices			
Smoking Status	Type of smoker based on respondent's smoking habits	• Daily smoker • Occasional smoker (former daily smoker) • Occasional smoker (<100 cigarettes lifetime) • Former daily smoker • Former occasional smoker • Never smoked	• *Never smoked* • Former smoker • Smoker
Exposure to 2nd hand smoke	Regular exposure to second hand smoke	In home Yes/No Private vehicle Yes/No Public place Yes/No	• *No* (no to all) • Yes (yes to any)
Alcohol Use	Type of drinker based upon average daily alcohol consumption	Continuous	• *Non-drinker* • ≥ 1 drink per day
Typical daily activity	Indicates usual activity	• Usually sit • Stand or walk • Lift light loads • Lift heavy loads	• *Usually sit* • Stand or walk • Lift light/heavy loads

* Reference category is *italicized*

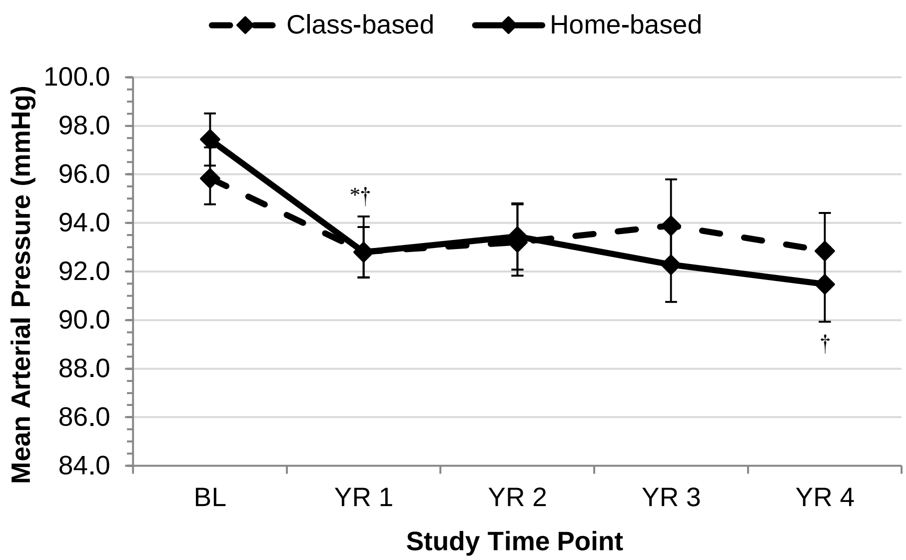
Table B.1 continued

Variable	CCHS Questionnaire Item	CCHS Variable Coding	Final Variable Coding
Time spent walking	Indicates time spent daily walking to work and/or to do errands	• None • < 1 hour • 1 – 5 hours • 6 – 10 hours • 11 – 20 hours • > 20 hours	• *None* • < 1 hour • ≥1hour
Biking for work/ errands	Indicates time spent daily biking to work and/or to do errands	• None • < 1 hour • 1 – 5 hours • 6 – 10 hours • 11 – 20 hours • > 20 hours	• *None* • Yes
Environmental Factors			
Province	Province of residence	• NL • PE • NS • NB • QC • ON	• MB • SK • AB • BC • YT • NT • NU
Urban-rural residence	Classifies where the respondent lives as an urban or rural area based on postal code	• Urban • Rural	• *Urban* • Rural

* Reference category is *italicized*

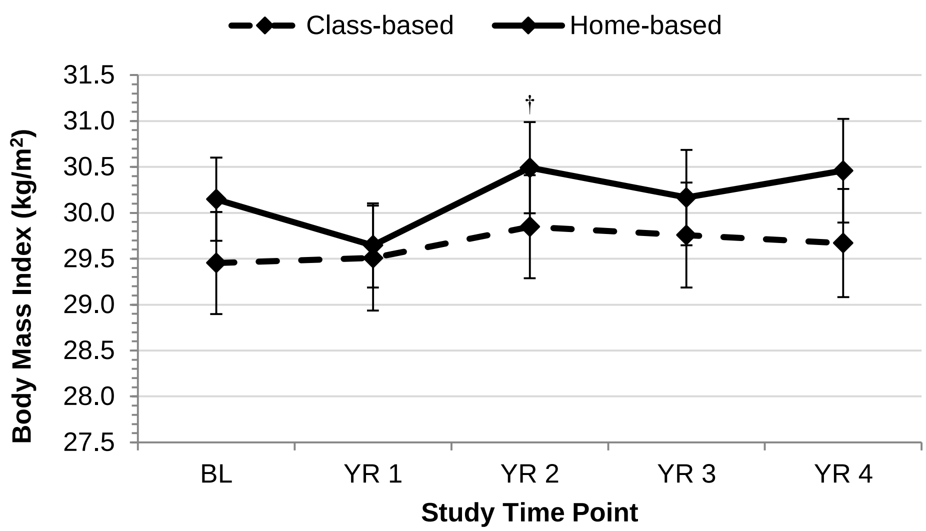
APPENDIX C-1

50 + *in motion* Intervention Outcomes (Figures)



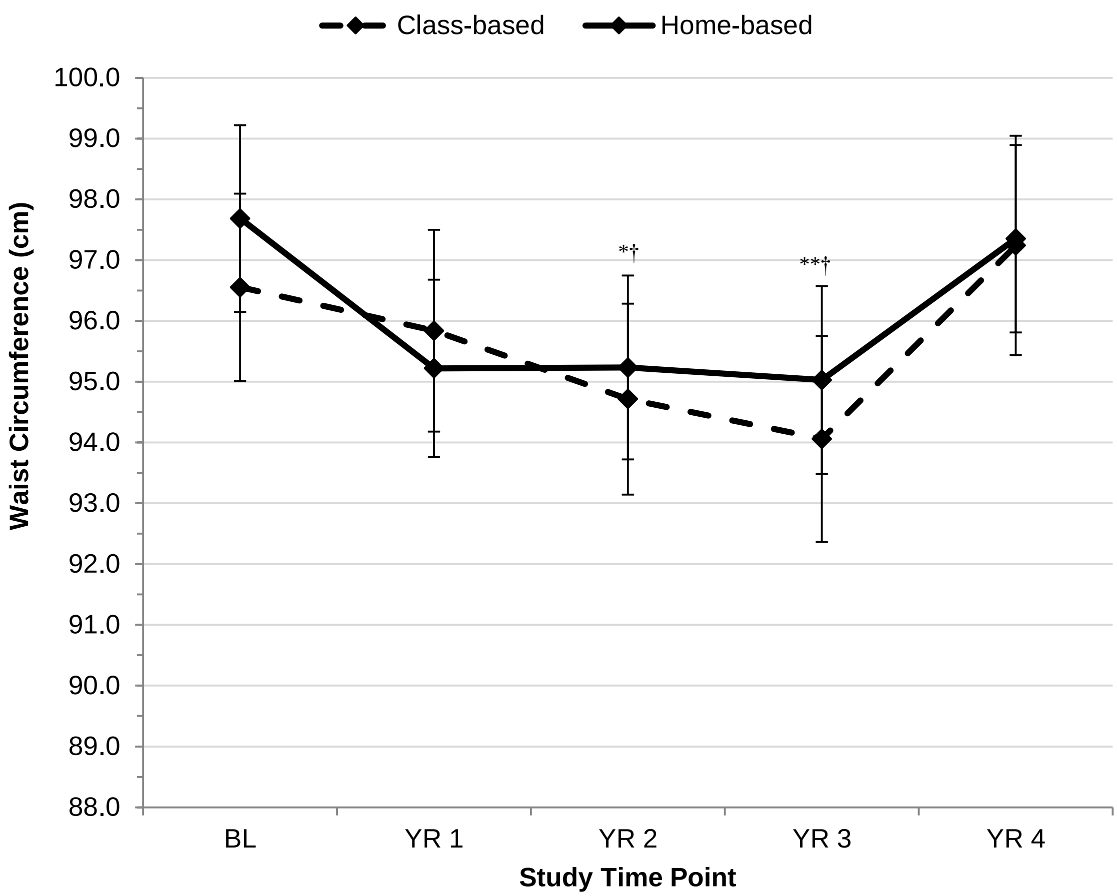
* Significantly different than baseline (overall) ($p \leq .001$)
† Significantly different than baseline (within-group – HB only) ($p < .01$)

Figure C.1: Changes in mean arterial pressure over the 4-years following the 50+ *in motion* intervention, by intervention group



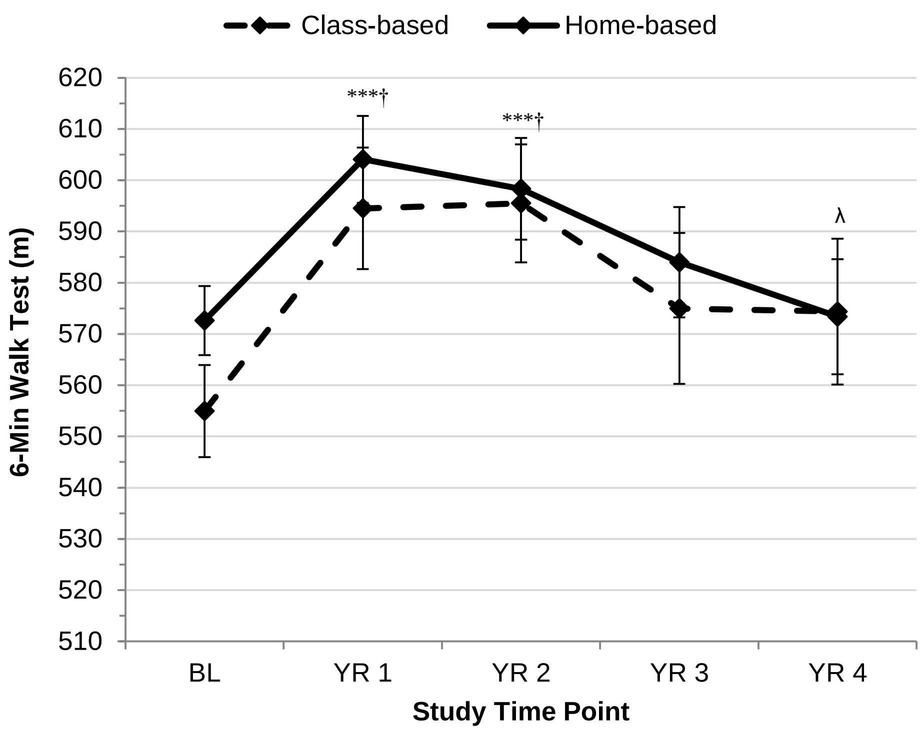
* Significantly different than baseline (overall) ($p \leq .05$)
† Significantly different than baseline (within-group – HB only) ($p < .05$)

Figure C.2: Changes in body mass index over the 4-years following the 50+ *in motion* intervention, by intervention group



* Significantly different than baseline (overall) (*p*≤ .05)
** Significantly different than baseline (overall) (*p*≤ .01)
† Significantly different than baseline (within-group – both CB and HB) (*p*< .05)

Figure C.3: Changes in waist circumference over the 4-years following the 50+ in motion intervention, by intervention group

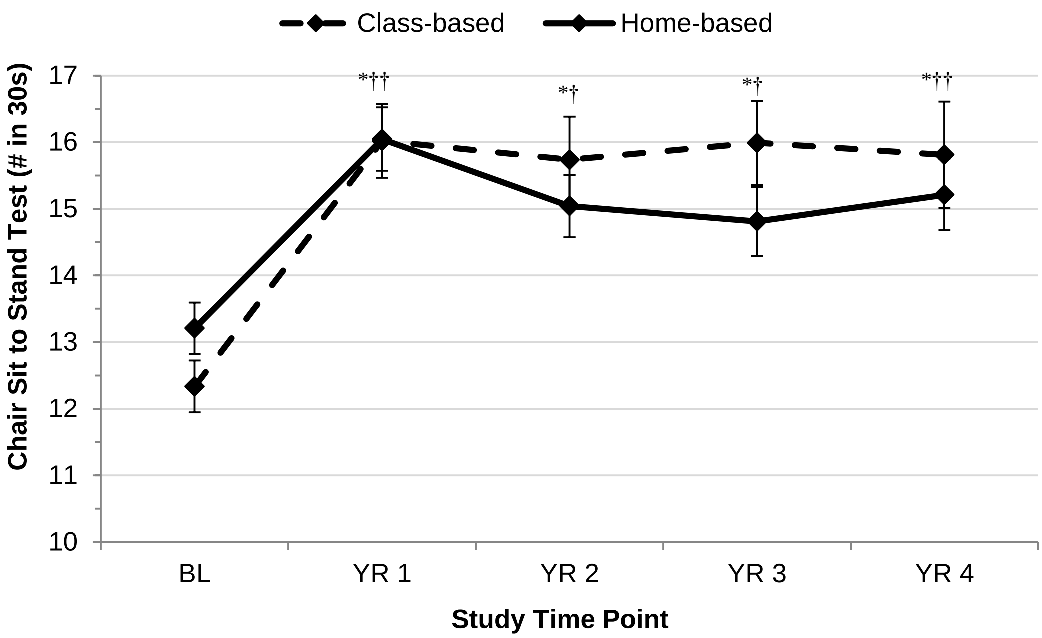


*** Significantly different than baseline (overall) ($p \leq .001$)

† Significantly different than baseline (within-group – both CB and HB; $p < .001$ and $p < .05$, respectively)

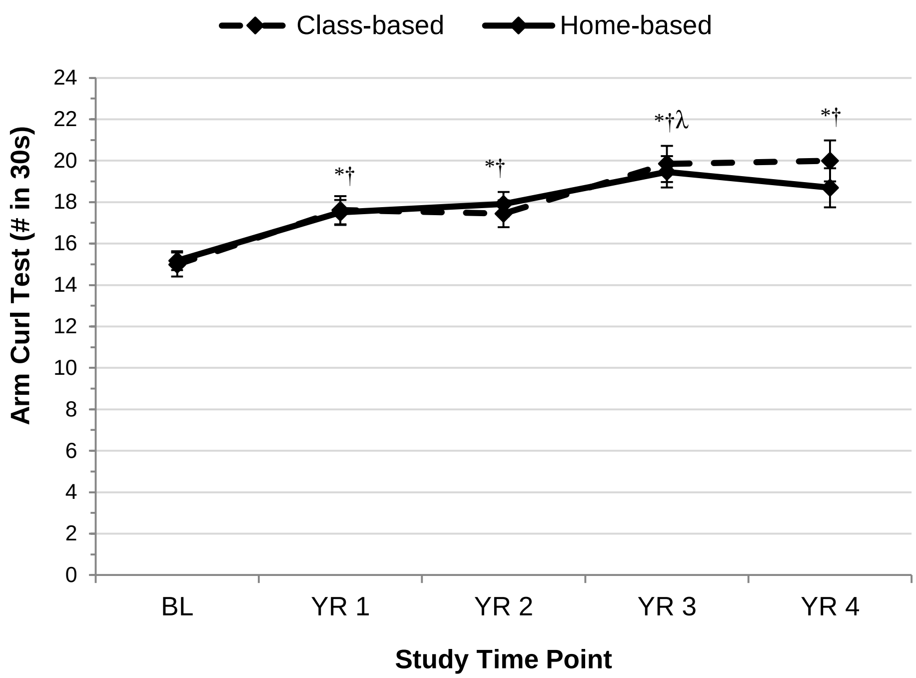
λ Significantly different than Yr.1 (within-group – HB only, $p < .05$)

Figure C.4: Changes in cardiovascular endurance over the 4-years following the 50+ *in motion* intervention, by intervention group



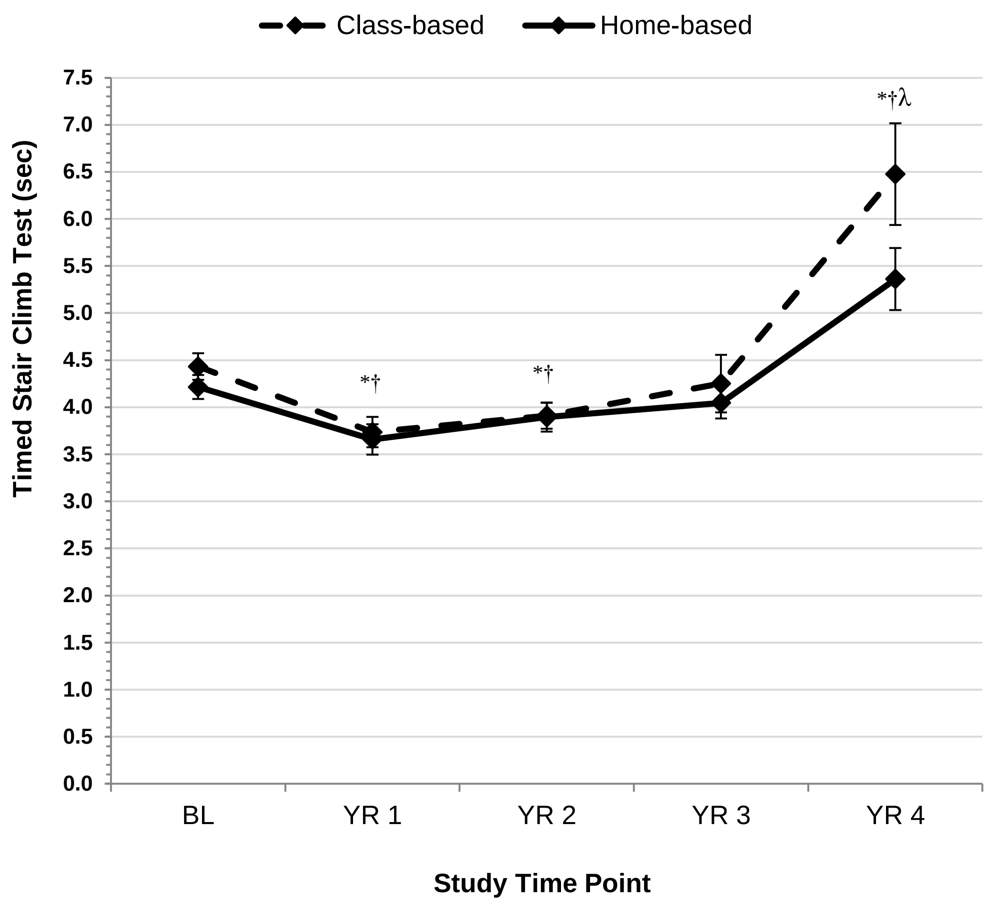
* Significantly different than baseline (overall) ($p \leq .001$)
†† Significantly different than baseline (within-group – both CB and HB; $p < .001$)
† Significantly different than baseline (within-group – both CB and HB; $p < .05$)

Figure C.5: Changes in lower body strength and endurance over the 4-years following the 50+ *in motion* intervention, by intervention group



* Significantly different than baseline (overall) ($p \leq .001$)
† Significantly different than baseline (within-group – both CB and HB; $p < .001$ and $p < .01$, respectively)
λ Significantly different than Yr.2 (CB) and Yr. 1 (CB and HB) (within-group – $p < .05$)

Figure C.6: Changes in upper body strength and endurance over the 4-years following the 50+ *in motion* intervention, by intervention group

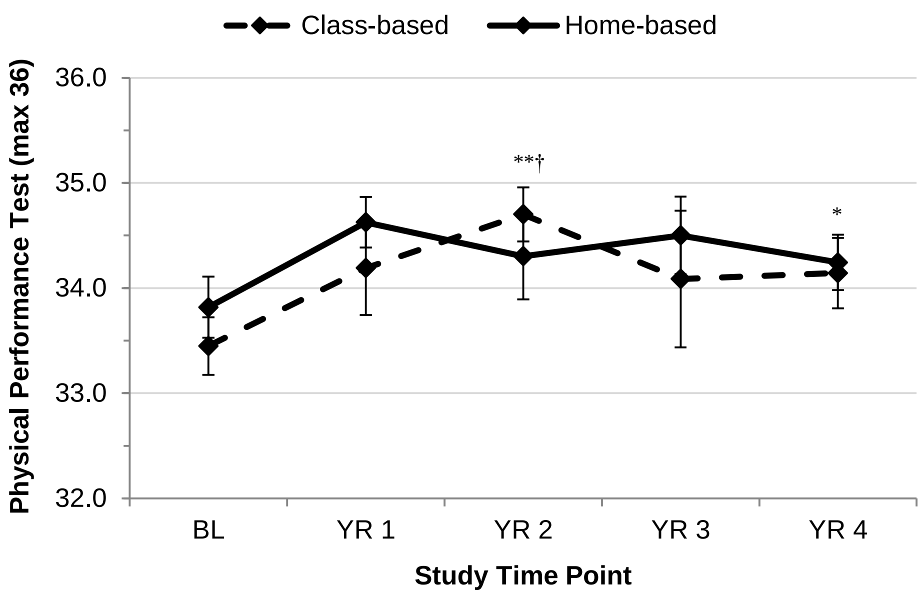


* Significantly different than baseline (overall) ($p \leq .001$)

† Significantly different than baseline (Yr.1-CB and HB; YR.2 – CB only, $p<.01$)

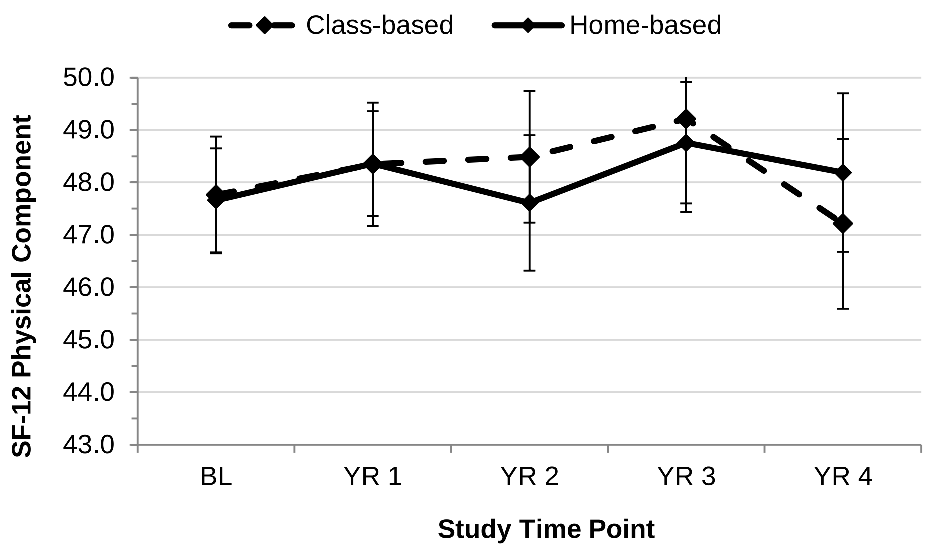
λ Significantly different than all other time points (within-group – both CB and HB; $p< .001$ and $p< .01$, respectively)

Figure C.7: Changes in lower body speed and power over the 4-years following the 50+ *in motion* intervention, by intervention group



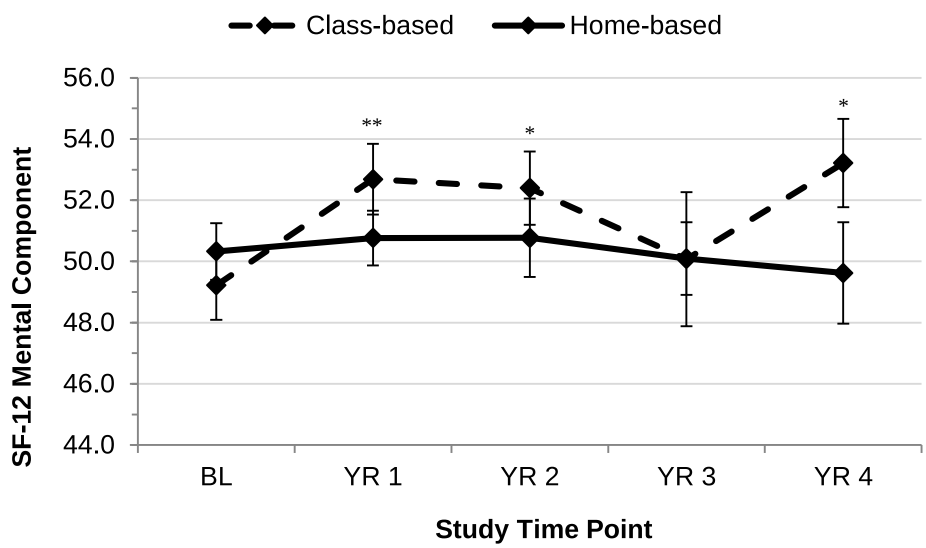
** Significantly different than baseline (overall) ($p \leq .001$)
* Significantly different than baseline (overall) ($p \leq .05$)
† Significantly different than baseline (CB only, $p < .001$)

Figure C.8: Changes in Physical Performance Test performance over the 4-years following the 50+ *in motion* intervention, by intervention group



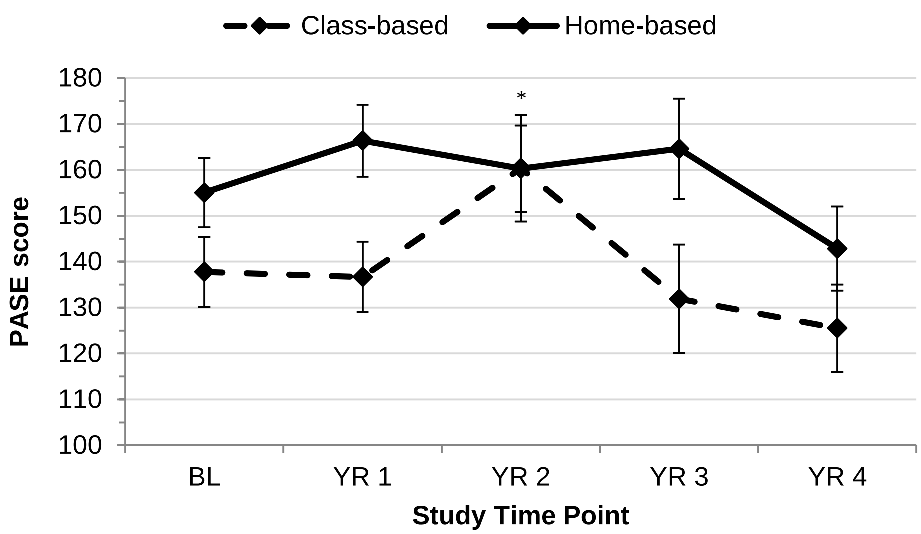
* Significantly different than baseline (overall, $p \leq .05$)
† Significantly different than baseline (within-group, $p \leq .05$)

Figure C.9: Changes in SF-12 Physical Component Summary Score over the 4-years following the 50+ *in motion* intervention, by intervention group



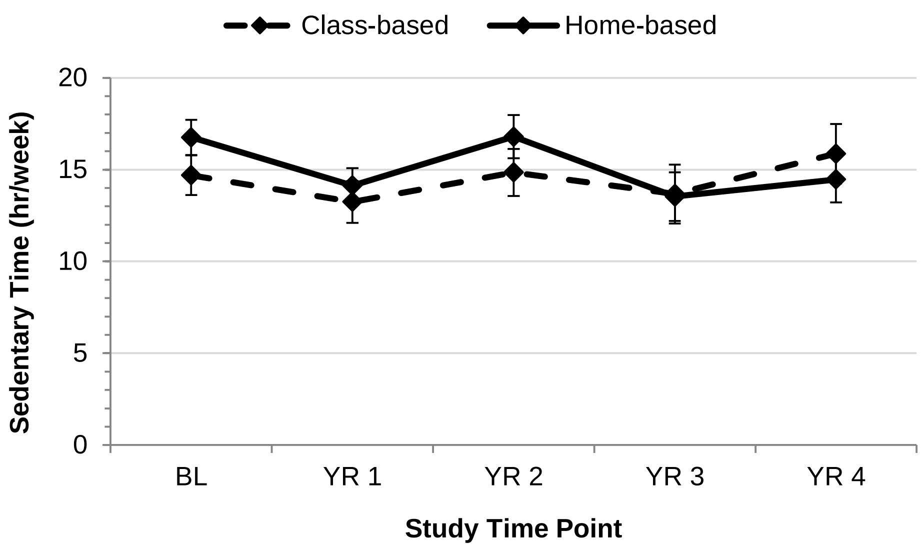
** Significantly different than baseline (overall, $p \leq .01$)
* Significantly different than baseline (overall, $p \leq .05$)

Figure C.10: Changes in SF-12 Mental Component Summary Score over the 4-years following the 50+ *in motion* intervention, by intervention group



* Significantly different than baseline (overall, $p \leq .05$)

Figure C.11: Changes in level of physical activity over the 4-years following the 50+ *in motion* intervention, by intervention group



* Significantly different than baseline (overall, $p \leq .05$)

Figure C.12: Changes in average weekly sedentary time over the 4-years following the 50+ *in motion* intervention, by intervention group

APPENDIX C-2

Study 2 Supplementary Data and Analytical Tables

Table C.1: Parameter estimates for the initial negative binomial GEE model of annual visits to GP physicians.

Parameter	B	SE	95% Wald CI		Hypothesis Test			Exp(B)	95% Wald CI for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	2.092	.7683	.586	3.598	7.415	1	.006	8.102	1.797	36.526
[timepoint=4]	-.007	.1453	-.292	.278	.002	1	.962	.993	.747	1.320
[timepoint=3]	.366	.1393	.093	.639	6.914	1	.009	1.442	1.098	1.895
[timepoint=2]	.272	.1166	.043	.501	5.436	1	.020	1.312	1.044	1.650
[timepoint=1]	.028	.1066	-.181	.237	.068	1	.795	1.028	.834	1.267
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing=5]	.251	.1253	.005	.497	4.014	1	.045	1.285	1.005	1.643
[missing=4]	.059	.1441	-.224	.341	.165	1	.685	1.060	.799	1.406
[missing=3]	.049	.1587	-.262	.360	.097	1	.755	1.051	.770	1.434
[missing=2]	-.030	.1748	-.372	.313	.028	1	.866	.971	.689	1.368
[missing=1]	.100	.1363	-.167	.368	.543	1	.461	1.106	.846	1.444
[missing=0]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	.144	.1237	-.098	.387	1.363	1	.243	1.155	.907	1.472
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	.472	.1748	.130	.815	7.304	1	.007	1.604	1.139	2.259
[timepoint=3] * [random=2]	-.083	.1596	-.395	.230	.267	1	.605	.921	.673	1.259
[timepoint=2] * [random=2]	.006	.1263	-.242	.253	.002	1	.964	1.006	.785	1.288
[timepoint=1] * [random=2]	.163	.1132	-.059	.385	2.082	1	.149	1.177	.943	1.470
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
age_calc	.006	.0073	-.008	.020	.676	1	.411	1.006	.992	1.021
[smoke_2cat=1.00]	.187	.0969	-.002	.377	3.742	1	.053	1.206	.998	1.458
[smoke_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
num_cc	.103	.0279	.048	.158	13.573	1	.000	1.108	1.049	1.171
pcs_12	-.008	.0045	-.017	.001	3.123	1	.077	.992	.984	1.001
MAP	-.005	.0030	-.011	.001	2.429	1	.119	.995	.990	1.001
distance	.000	.0006	-.001	.001	.167	1	.683	1.000	.999	1.001
chairstand	-.020	.0126	-.044	.005	2.482	1	.115	.980	.957	1.005
armcurl	.004	.0067	-.009	.017	.285	1	.593	1.004	.991	1.017
(Scale)	1									
(Negative binomial)	1[b]									

Dependent Variable: number of visits to family dr
Model: (Intercept), timepoint, missing, random, timepoint * random, age_calc, smoke_2cat, num_cc, pcs_12, MAP, distance, chairstand, armcurl
a. Set to zero because this parameter is redundant.
b. Fixed at the displayed value.

Table C.2: Parameter estimates for the final negative binomial GEE model of annual visits to GP physicians.

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	2.262	.3405	1.594	2.929	44.117	1	.000
[timepoint=4]	.053	.1393	-.220	.326	.144	1	.705
[timepoint=3]	.431	.1474	.142	.720	8.542	1	.003
[timepoint=2]	.314	.1136	.091	.536	7.614	1	.006
[timepoint=1]	.075	.0989	-.119	.268	.570	1	.450
[timepoint=0]	0[a]	.	.	.	.	.	.
[missing=5]	.234	.1265	-.014	.482	3.424	1	.064
[missing=4]	.101	.1087	-.112	.314	.861	1	.354
[missing=3]	-.022	.1600	-.335	.292	.018	1	.892
[missing=2]	.022	.1701	-.312	.355	.016	1	.899
[missing=1]	.145	.1375	-.125	.414	1.107	1	.293
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	.144	.1250	-.101	.389	1.335	1	.248
[random=1]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	.455	.1762	.110	.800	6.669	1	.010
[random=2] * [timepoint=3]	-.093	.1625	-.411	.226	.327	1	.567
[random=2] * [timepoint=2]	.018	.1280	-.232	.269	.021	1	.886
[random=2] * [timepoint=1]	.166	.1137	-.057	.389	2.127	1	.145
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
num_cc	.105	.0290	.048	.162	13.194	1	.000
pcs_12	-.009	.0046	-.017	.000	3.478	1	.062
distance	.000	.0005	-.001	.001	.542	1	.462
chairstand	-.019	.0117	-.042	.004	2.706	1	.100
(Scale)	1						
(Negative binomial)	1[b]						

Dependent Variable: number of visits to family dr

Model: (Intercept), timepoint, missing, random, timepoint * random, num_cc, pcs_12, distance, chairstand

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

Table C.3: Parameter estimates for the initial binomial (logit) GEE model of frequent use of GP services.

Parameter	B	SE	95% Wald C.I.		Hypothesis Test			Exp(B)	95% Wald C.Ifor Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	-.654	4.1562	-8.800	7.492	.025	1	.875	.520	.000	1794.270
[timepoint=4]	.958	.7916	-.594	2.509	1.464	1	.226	2.606	.552	12.295
[timepoint=3]	2.450	.6106	1.253	3.647	16.101	1	.000	11.589	3.502	38.353
[timepoint=2]	1.093	.4559	.199	1.986	5.745	1	.017	2.982	1.220	7.287
[timepoint=1]	-.666	.7310	-2.099	.766	.831	1	.362	.514	.123	2.152
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	.486	.7143	-.914	1.886	.463	1	.496	1.626	.401	6.594
[missing_rc=2.00]	1.226	.6261	-.001	2.453	3.836	1	.050	3.408	.999	11.626
[missing_rc=1.00]	1.106	.5098	.107	2.105	4.706	1	.030	3.022	1.113	8.208
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	.522	.5493	-.555	1.598	.902	1	.342	1.685	.574	4.944
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	.953	1.0017	-1.010	2.916	.905	1	.341	2.593	.364	18.469
[timepoint=3] * [random=2]	-.999	.7346	-2.439	.441	1.850	1	.174	.368	.087	1.554
[timepoint=2] * [random=2]	.116	.5867	-1.034	1.266	.039	1	.844	1.123	.356	3.546
[timepoint=1] * [random=2]	1.085	.8120	-.507	2.676	1.784	1	.182	2.958	.602	14.526
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
[edcat_2=1.00]	.996	.8956	-.760	2.751	1.236	1	.266	2.706	.468	15.657
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
PASE_total	.000	.0021	-.004	.004	.007	1	.933	1.000	.996	1.004
distance	-.004	.0030	-.010	.002	1.797	1	.180	.996	.990	1.002
chairstand	-.037	.0442	-.123	.050	.695	1	.405	.964	.884	1.051
PPT_total	-.043	.0624	-.165	.079	.472	1	.492	.958	.848	1.083
pcs_12	-.028	.0203	-.067	.012	1.866	1	.172	.973	.935	1.012
num_cc	.245	.1083	.032	.457	5.103	1	.024	1.277	1.033	1.579
BMI_st	-.056	.0720	-.197	.085	.611	1	.434	.945	.821	1.089
WC	.034	.0204	-.006	.074	2.720	1	.099	1.034	.994	1.076
age_calc	.005	.0364	-.067	.076	.017	1	.897	1.005	.935	1.079
(Scale)	1									

Dependent Variable: GP visits - frequent user

Model: (Intercept), timepoint, missing_rc, random, timepoint * random, edcat_2, PASE_total, distance, chairstand, PPT_total, pcs_12, num_cc, BMI_st, WC, age_calc

a. Set to zero because this parameter is redundant.

Table C.4: Parameter estimates for the final binomial (logit) GEE model of frequent use of GP services.

Parameter	B	SE	95% Wald C.I.		Hypothesis Test			Exp(B)	95% Wald C.I. for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	.082	1.5254	-2.908	3.072	.003	1	.957	1.085	.055	21.579
[timepoint=4]	.350	.9168	-1.447	2.147	.145	1	.703	1.418	.235	8.555
[timepoint=3]	2.117	.5287	1.081	3.153	16.033	1	.000	8.306	2.947	23.410
[timepoint=2]	.863	.3924	.094	1.632	4.834	1	.028	2.370	1.098	5.113
[timepoint=1]	-.718	.6665	-2.025	.588	1.162	1	.281	.487	.132	1.800
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	.348	.6859	-.997	1.692	.257	1	.612	1.416	.369	5.430
[missing_rc=2.00]	1.012	.5928	-.150	2.173	2.912	1	.088	2.750	.860	8.788
[missing_rc=1.00]	.891	.4813	-.052	1.835	3.430	1	.064	2.439	.949	6.263
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	.502	.5350	-.546	1.551	.881	1	.348	1.652	.579	4.715
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	1.313	1.1108	-.864	3.490	1.397	1	.237	3.717	.421	32.787
[timepoint=3] * [random=2]	-1.028	.7057	-2.411	.355	2.121	1	.145	.358	.090	1.427
[timepoint=2] * [random=2]	.068	.5522	-1.014	1.151	.015	1	.902	1.071	.363	3.160
[timepoint=1] * [random=2]	.939	.7629	-.557	2.434	1.514	1	.219	2.556	.573	11.404
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_cc	.208	.0990	.014	.402	4.396	1	.036	1.231	1.014	1.494
[edcat_2=1.00]	1.130	.8168	-.470	2.731	1.916	1	.166	3.097	.625	15.352
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
distance	-.004	.0023	-.009	.000	3.576	1	.059	.996	.991	1.000
pcs_12	-.035	.0186	-.072	.001	3.574	1	.059	.965	.931	1.001
(Scale)	1									

Dependent Variable: GP visits - frequent user

Model: (Intercept), timepoint, missing_rc, random, timepoint * random, num_cc, edcat_2, distance, pcs_12

a. Set to zero because this parameter is redundant.

Table C.5: Parameter estimates for the initial linear GEE model of log-transformed annual costs of GP services.

Parameter	B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	1.332	.3399	.666	1.998	15.360	1	.000
[missing=5]	.020	.0436	-.065	.106	.216	1	.642
[missing=4]	.292	.0728	.150	.435	16.146	1	.000
[missing=3]	-.076	.0630	-.200	.047	1.471	1	.225
[missing=2]	-.033	.0886	-.207	.140	.142	1	.706
[missing=1]	.075	.0389	-.001	.152	3.748	1	.053
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	.066	.0526	-.037	.169	1.564	1	.211
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	-.095	.1348	-.359	.169	.497	1	.481
[timepoint=3]	.027	.0677	-.105	.160	.164	1	.686
[timepoint=2]	.056	.0860	-.112	.225	.426	1	.514
[timepoint=1]	-.015	.0591	-.131	.100	.068	1	.795
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	.114	.1404	-.162	.389	.655	1	.418
[random=2] * [timepoint=3]	.076	.0980	-.116	.268	.598	1	.439
[random=2] * [timepoint=2]	-.008	.0969	-.198	.182	.007	1	.932
[random=2] * [timepoint=1]	.086	.0599	-.032	.203	2.056	1	.152
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
[income_2cat=1.00]	-.081	.0344	-.148	-.013	5.501	1	.019
[income_2cat=.00]	0[a]	.	.	.	.	.	.
[smoke_2cat=1.00]	-.030	.0380	-.104	.045	.603	1	.438
[smoke_2cat=.00]	0[a]	.	.	.	.	.	.
num_gpvisits	.070	.0060	.058	.082	135.605	1	.000
num_spvisits	.000	.0019	-.003	.004	.045	1	.833
num_cc	.007	.0121	-.017	.031	.312	1	.576
pcs_12	.001	.0020	-.003	.005	.252	1	.616
age_calc	.003	.0030	-.003	.009	1.192	1	.275
distance	.001	.0002	2.505E-005	.001	4.254	1	.039
chairstand	-.013	.0136	-.039	.014	.861	1	.353
armcurl	-.001	.0037	-.009	.006	.150	1	.698
ppt8_time	.012	.0106	-.009	.033	1.334	1	.248
(Scale)	.105						

Dependent Variable: transformed gp costs

Model: (Intercept), missing, random, timepoint, random * timepoint, income_2cat, smoke_2cat, num_gpvisits, num_spvisits, num_cc, pcs_12, age_calc, distance, chairstand, armcurl, ppt8_time

a. Set to zero because this parameter is redundant.

Table C.6: Parameter estimates for the final linear GEE model of log-transformed annual costs of GP services.

Parameter			95% Wald Confidence Interval		Hypothesis Test		
	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	1.311	.3308	.663	1.960	15.709	1	.000
[missing=5]	.020	.0430	-.065	.104	.213	1	.645
[missing=4]	.276	.0639	.151	.401	18.646	1	.000
[missing=3]	-.064	.0632	-.188	.060	1.018	1	.313
[missing=2]	-.044	.0895	-.220	.131	.246	1	.620
[missing=1]	.071	.0379	-.003	.145	3.529	1	.060
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	.059	.0519	-.043	.161	1.302	1	.254
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	-.101	.1355	-.367	.165	.556	1	.456
[timepoint=3]	.020	.0671	-.112	.151	.087	1	.767
[timepoint=2]	.054	.0864	-.115	.223	.392	1	.531
[timepoint=1]	-.019	.0592	-.135	.098	.098	1	.754
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	.120	.1409	-.156	.396	.723	1	.395
[random=2] * [timepoint=3]	.081	.0973	-.109	.272	.699	1	.403
[random=2] * [timepoint=2]	-.005	.0978	-.196	.187	.002	1	.961
[random=2] * [timepoint=1]	.091	.0601	-.027	.208	2.278	1	.131
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
[income_2cat=1.00]	-.076	.0329	-.140	-.011	5.277	1	.022
[income_2cat=.00]	0[a]	.	.	.	.	.	.
num_gpvisits	.070	.0060	.058	.082	136.500	1	.000
num_cc	.008	.0124	-.017	.032	.392	1	.531
distance	.000	.0002	3.452E-005	.001	4.448	1	.035
pcs_12	.001	.0020	-.003	.005	.244	1	.621
age_calc	.003	.0030	-.002	.009	1.353	1	.245
chairstand	-.013	.0126	-.038	.011	1.150	1	.284
ppt8_time	.012	.0104	-.009	.032	1.243	1	.265
(Scale)	.104						

Dependent Variable: transformed gp costs
Model: (Intercept), missing, random, timepoint, random * timepoint, income_2cat, num_gpvisits, num_cc, distance, pcs_12, age_calc, chairstand, ppt8_time
a. Set to zero because this parameter is redundant (additional redundant random*timepoint estimates removed for space)

Table C.7: Parameter estimates for the initial binomial GEE model of use of specialist physician services

Parameter			95% Wald C.I		Hypothesis Test				95% Wald C.I. for Exp(B)	
	B	SE	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	1.392	5.5384	-9.463	12.248	.063	1	.801	4.025	7.770E-005	208487.274
[timepoint=4]	.786	.9397	-1.056	2.628	.700	1	.403	2.195	.348	13.846
[timepoint=3]	-.520	.8325	-2.152	1.111	.390	1	.532	.594	.116	3.039
[timepoint=2]	.744	.6729	-.575	2.063	1.223	1	.269	2.105	.563	7.872
[timepoint=1]	.914	.5716	-.206	2.035	2.559	1	.110	2.495	.814	7.650
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.600	.5286	-1.636	.436	1.290	1	.256	.549	.195	1.546
[missing_rc=2.00]	-1.061	.5247	-2.089	-.032	4.088	1	.043	.346	.124	.968
[missing_rc=1.00]	-.459	.4761	-1.392	.475	.927	1	.336	.632	.249	1.608
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	-.199	.5712	-1.319	.920	.122	1	.727	.819	.267	2.511
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-1.427	1.1071	-3.596	.743	1.661	1	.198	.240	.027	2.103
[timepoint=3] * [random=2]	.915	.9967	-1.039	2.868	.842	1	.359	2.496	.354	17.605
[timepoint=2] * [random=2]	-.114	.8144	-1.710	1.482	.020	1	.889	.892	.181	4.402
[timepoint=1] * [random=2]	.685	.7069	-.701	2.070	.939	1	.333	1.984	.496	7.929
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	.270	.0763	.121	.420	12.535	1	.000	1.310	1.128	1.522
[gender=1]	-.017	.4798	-.957	.924	.001	1	.972	.983	.384	2.518
[gender=0]	0[a]	.	.	.	.	.	.	1	.	.
[marital_2cat=1.00]	.235	.5080	-.761	1.231	.214	1	.644	1.265	.467	3.424
[marital_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
[income_2cat=1.00]	-.825	.8307	-2.453	.803	.986	1	.321	.438	.086	2.233
[income_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
PASE_total	.001	.0022	-.003	.006	.423	1	.515	1.001	.997	1.006
distance	-.002	.0041	-.010	.006	.186	1	.667	.998	.990	1.006
chairstand	-.149	.0671	-.280	-.017	4.908	1	.027	.862	.756	.983
armcurl	.014	.0369	-.058	.087	.150	1	.698	1.014	.944	1.091
PPT_total	.061	.1390	-.212	.333	.189	1	.663	1.062	.809	1.395
ppt8_time	.106	.1103	-.110	.323	.932	1	.334	1.112	.896	1.381
pcs_12	.002	.0222	-.041	.046	.009	1	.925	1.002	.959	1.047
num_cc	.572	.1523	.274	.871	14.126	1	.000	1.772	1.315	2.389
BMI_st	-.006	.0756	-.154	.142	.006	1	.940	.994	.857	1.153
WC	-.006	.0252	-.055	.044	.051	1	.822	.994	.946	1.045
age_calc	-.005	.0340	-.072	.061	.024	1	.876	.995	.931	1.063
(Scale)	1									

Dependent Variable: specialist visits - flag

Model: (Intercept), timepoint, missing_rc, random, timepoint * random, num_gpvisits, gender, marital_2cat, income_2cat, PASE_total, distance, chairstand, armcurl, PPT_total, ppt8_time, pcs_12, num_cc, BMI_st, WC, age_calc

a. Set to zero because this parameter is redundant.

Table C.8: Parameter estimates for the final binomial GEE model of use specialist physician services

Parameter			95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
	B	SE	Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	1.977	1.1076	-.194	4.148	3.187	1	.074	7.223	.824	63.312
[timepoint=4]	.868	.7761	-.653	2.389	1.251	1	.263	2.382	.520	10.906
[timepoint=3]	-.432	.7479	-1.898	1.034	.334	1	.564	.649	.150	2.812
[timepoint=2]	.836	.6131	-.366	2.038	1.859	1	.173	2.307	.694	7.672
[timepoint=1]	.895	.5043	-.093	1.883	3.151	1	.076	2.448	.911	6.576
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.379	.5091	-1.377	.619	.554	1	.457	.685	.252	1.857
[missing_rc=2.00]	-.900	.4831	-1.847	.047	3.472	1	.062	.407	.158	1.048
[missing_rc=1.00]	-.278	.4287	-1.118	.562	.420	1	.517	.757	.327	1.755
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	-.120	.5436	-1.186	.945	.049	1	.825	.887	.306	2.573
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-1.088	1.0281	-3.103	.927	1.120	1	.290	.337	.045	2.526
[timepoint=3] * [random=2]	.999	.9104	-.786	2.783	1.203	1	.273	2.714	.456	16.165
[timepoint=2] * [random=2]	-.318	.7663	-1.820	1.184	.172	1	.678	.727	.162	3.266
[timepoint=1] * [random=2]	.506	.6727	-.813	1.824	.566	1	.452	1.658	.444	6.198
[timepoint=1] * [random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=0] * [random=1]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	.220	.0783	.067	.373	7.897	1	.005	1.246	1.069	1.453
[income_2cat=1.00]	-.716	.5758	-1.845	.412	1.548	1	.213	.489	.158	1.510
[income_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
chairstand	-.141	.0419	-.223	-.059	11.309	1	.001	.869	.800	.943
num_cc	.606	.1436	.325	.888	17.831	1	.000	1.834	1.384	2.430
pcs_12	.006	.0191	-.031	.044	.114	1	.735	1.006	.970	1.045
(Scale)	1									

Dependent Variable: specialist visits - flag

Model: (Intercept), timepoint, missing_rc, random, timepoint * random, num_gpvisits, income_2cat, chairstand, num_cc, pcs_12

a. Set to zero because this parameter is redundant.

Table C.9: Parameter estimates for the initial negative binomial GEE model of annual number of specialist physician services

			95% Wald CI		Hypothesis Test				95% Wald CI for Exp(B)	
Parameter	B	SE	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	-1.753	1.4617	-4.618	1.112	1.438	1	.230	.173	.010	3.040
[timepoint=4]	.149	.2378	-.317	.616	.395	1	.530	1.161	.729	1.851
[timepoint=3]	-.107	.2218	-.542	.327	.234	1	.628	.898	.581	1.387
[timepoint=2]	.295	.2060	-.109	.698	2.045	1	.153	1.343	.897	2.010
[timepoint=1]	.356	.1891	-.014	.727	3.554	1	.059	1.428	.986	2.069
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.304	.2988	-.890	.281	1.038	1	.308	.738	.411	1.325
[missing_rc=2.00]	-.346	.2608	-.857	.165	1.758	1	.185	.708	.424	1.180
[missing_rc=1.00]	-.213	.2649	-.732	.307	.644	1	.422	.808	.481	1.359
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	-.274	.1721	-.612	.063	2.543	1	.111	.760	.542	1.065
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-.303	.3936	-1.074	.469	.592	1	.442	.739	.342	1.598
[timepoint=3] * [random=2]	.509	.3082	-.095	1.113	2.724	1	.099	1.663	.909	3.042
[timepoint=2] * [random=2]	.280	.2761	-.261	.821	1.029	1	.310	1.323	.770	2.273
[timepoint=1] * [random=2]	.397	.2243	-.043	.836	3.130	1	.077	1.487	.958	2.308
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	.092	.0103	.072	.112	79.635	1	.000	1.096	1.074	1.119
[gender=1]	.547	.2040	.148	.947	7.203	1	.007	1.729	1.159	2.578
[gender=0]	0[a]	.	.	.	.	.	.	1	.	.
age_calc	.019	.0110	-.003	.040	2.866	1	.090	1.019	.997	1.041
num_cc	.116	.0384	.040	.191	9.046	1	.003	1.122	1.041	1.210
[edcat_2=1.00]	.111	.1716	-.225	.448	.422	1	.516	1.118	.799	1.565
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
WC	.005	.0054	-.006	.015	.787	1	.375	1.005	.994	1.016
sed_week	.005	.0069	-.008	.019	.617	1	.432	1.005	.992	1.019
PASE_total	.002	.0016	-.002	.005	.957	1	.328	1.002	.998	1.005
MAP	-.003	.0063	-.015	.009	.261	1	.610	.997	.985	1.009
distance	.002	.0010	.000	.004	2.823	1	.093	1.002	1.000	1.004
chairstand	-.075	.0219	-.118	-.032	11.842	1	.001	.927	.888	.968
pcs_12	-.004	.0094	-.022	.015	.168	1	.682	.996	.978	1.015
ppt8_time	.075	.0357	.005	.145	4.430	1	.035	1.078	1.005	1.156
(Scale)	1									
(Negative binomial)	1[b]									

Dependent Variable: number of visits to medical specialist
Model: (Intercept), random, timepoint, missing_rc, timepoint * random, num_gpvisits, gender, age_calc, num_cc, edcat_2, WC, sed_week, PASE_total, MAP, distance, chairstand, pcs_12, ppt8_time
a. Set to zero because this parameter is redundant.
b. Fixed at the displayed value.

Table C.10: Parameter estimates for the final negative binomial GEE model of annual number of specialist physician services

Parameter	B	SE	95% Wald CI		Hypothesis Test			Exp(B)	95% Wald CI for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	-1.563	.9267	-3.380	.253	2.846	1	.092	.209	.034	1.288
[timepoint=4]	.032	.1974	-.355	.419	.026	1	.871	1.033	.701	1.520
[timepoint=3]	-.365	.2121	-.781	.050	2.967	1	.085	.694	.458	1.052
[timepoint=2]	.174	.2072	-.232	.580	.707	1	.400	1.190	.793	1.786
[timepoint=1]	.175	.1557	-.131	.480	1.257	1	.262	1.191	.878	1.616
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.181	.2732	-.717	.354	.441	1	.507	.834	.488	1.425
[missing_rc=2.00]	-.256	.2464	-.739	.227	1.082	1	.298	.774	.477	1.254
[missing_rc=1.00]	-.104	.2388	-.572	.364	.190	1	.663	.901	.564	1.439
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	-.241	.1604	-.555	.074	2.252	1	.133	.786	.574	1.076
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-.292	.3557	-.989	.405	.676	1	.411	.747	.372	1.499
[timepoint=3] * [random=2]	.700	.2895	.133	1.268	5.851	1	.016	2.014	1.142	3.553
[timepoint=2] * [random=2]	.312	.2980	-.273	.896	1.093	1	.296	1.366	.761	2.449
[timepoint=1] * [random=2]	.440	.2252	-.001	.881	3.819	1	.051	1.553	.999	2.414
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
[gender=1]	.452	.1533	.151	.752	8.677	1	.003	1.571	1.163	2.122
[gender=0]	0[a]								.	.
age_calc	.020	.0095	.001	.038	4.203	1	.040	1.020	1.001	1.039
num_gpvisits	.090	.0105	.070	.111	74.792	1	.000	1.095	1.072	1.117
num_cc	.099	.0383	.024	.174	6.720	1	.010	1.104	1.024	1.190
distance	.002	.0009	7.499E-5	.004	4.159	1	.041	1.002	1.000	1.004
chairstand	-.065	.0212	-.107	-.024	9.524	1	.002	.937	.899	.976
ppt8_time	.079	.0334	.013	.144	5.546	1	.019	1.082	1.013	1.155
(Scale)	1									
(Negative binomial)	1[b]									

Dependent Variable: number of visits to family dr
Model: (Intercept), timepoint, missing, random, timepoint * random, age_calc, smoke_2cat, num_cc, pcs_12, MAP, distance, chairstand, armcurl
a. Set to zero because this parameter is redundant.
b. Fixed at the displayed value.

Table C.11: Parameter estimates for the initial binomial (logit) GEE model of frequent use of specialist physician services

Parameter	B	Std. Error	95% Wald C.I.		Hypothesis Test			Exp(B)	95% Wald C.I. for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	-7.676	3.9879	-15.492	.140	3.705	1	.054	.000	1.870E-007	1.150
[timepoint=4]	1.605	.6273	.375	2.834	6.546	1	.011	4.978	1.456	17.020
[timepoint=3]	-.986	1.2859	-3.506	1.535	.588	1	.443	.373	.030	4.639
[timepoint=2]	.213	.7898	-1.335	1.761	.073	1	.788	1.237	.263	5.818
[timepoint=1]	1.194	.6523	-.084	2.473	3.351	1	.067	3.301	.919	11.855
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.068	.5809	-1.207	1.070	.014	1	.906	.934	.299	2.916
[missing_rc=2.00]	.578	.5809	-.560	1.717	.990	1	.320	1.783	.571	5.566
[missing_rc=1.00]	.209	.4965	-.764	1.182	.177	1	.674	1.232	.466	3.260
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	.149	.6324	-1.090	1.388	.056	1	.814	1.161	.336	4.008
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-2.063	.9338	-3.893	-.232	4.878	1	.027	.127	.020	.793
[timepoint=3] * [random=2]	2.256	1.3465	-.383	4.895	2.808	1	.094	9.547	.682	133.658
[timepoint=2] * [random=2]	.688	.8936	-1.064	2.439	.592	1	.442	1.989	.345	11.461
[timepoint=1] * [random=2]	-.334	.7279	-1.760	1.093	.210	1	.647	.716	.172	2.984
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	.156	.0336	.090	.222	21.558	1	.000	1.169	1.094	1.248
[gender=1]	.860	.5053	-.130	1.851	2.897	1	.089	2.363	.878	6.363
[gender=0]	0[a]	.	.	.	.	.	.	1	.	.
[marital_2cat=1.00]	-.257	.4360	-1.111	.598	.347	1	.556	.774	.329	1.818
[marital_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
[income_2cat=1.00]	-.868	.4097	-1.671	-.065	4.491	1	.034	.420	.188	.937
[income_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
PASE_total	.000	.0025	-.005	.005	.006	1	.938	1.000	.995	1.005
distance	.002	.0034	-.005	.008	.291	1	.589	1.002	.995	1.008
chairstand	-.018	.0494	-.115	.079	.130	1	.718	.982	.892	1.082
ppt8_time	.150	.1222	-.090	.389	1.498	1	.221	1.161	.914	1.476
pcs_12	.003	.0219	-.040	.046	.014	1	.905	1.003	.960	1.047
num_cc	.456	.1598	.143	.769	8.131	1	.004	1.577	1.153	2.158
age_calc	.034	.0327	-.030	.098	1.061	1	.303	1.034	.970	1.103
(Scale)	1									

Dependent Variable: Specialist - frequent user

Model: (Intercept), timepoint, missing_rc, random, timepoint * random, num_gpvisits, gender, marital_2cat, income_2cat, PASE_total, distance, chairstand, ppt8_time, pcs_12, num_cc, age_calc

a. Set to zero because this parameter is redundant.

Table C.12: Parameter estimates for the final binomial (logit) GEE model of frequent use of specialist physician services

Parameter	B	Std. Error	95% Wald C.I. Lower	95% Wald C.I. Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.	Exp(B)	95% Wald C.I. for Exp(B) Lower	95% Wald C.I. for Exp(B) Upper
(Intercept)	-9.249	4.1283	-17.341	-1.158	5.020	1	.025	9.618E-005	2.945E-008	.314
[timepoint=4]	1.571	.6428	.311	2.830	5.970	1	.015	4.810	1.364	16.953
[timepoint=3]	-1.202	1.3088	-3.767	1.364	.843	1	.359	.301	.023	3.911
[timepoint=2]	-.065	.8551	-1.741	1.611	.006	1	.939	.937	.175	5.007
[timepoint=1]	1.143	.6657	-.162	2.447	2.947	1	.086	3.135	.850	11.559
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.167	.5628	-1.270	.936	.088	1	.767	.846	.281	2.551
[missing_rc=2.00]	.454	.5846	-.692	1.600	.603	1	.437	1.575	.501	4.953
[missing_rc=1.00]	.367	.5084	-.629	1.364	.522	1	.470	1.444	.533	3.911
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[random=2]	-.138	.6223	-1.357	1.082	.049	1	.825	.871	.257	2.950
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-2.170	.9874	-4.105	-.234	4.828	1	.028	.114	.016	.791
[timepoint=3] * [random=2]	2.432	1.3669	-.247	5.111	3.167	1	.075	11.386	.781	165.911
[timepoint=2] * [random=2]	.814	.9386	-1.026	2.653	.752	1	.386	2.257	.359	14.202
[timepoint=1] * [random=2]	-.261	.7525	-1.735	1.214	.120	1	.729	.771	.176	3.368
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	.154	.0322	.091	.217	22.968	1	.000	1.167	1.095	1.243
[income_2cat=1.00]	-1.067	.4095	-1.869	-.264	6.789	1	.009	.344	.154	.768
[income_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
num_cc	.422	.1643	.100	.744	6.607	1	.010	1.525	1.105	2.105
pcs_12	.002	.0227	-.043	.047	.007	1	.932	1.002	.958	1.048
PASE_total	3.773E-005	.0029	-.006	.006	.000	1	.989	1.000	.994	1.006
distance	.003	.0038	-.004	.011	.831	1	.362	1.003	.996	1.011
chairstand	-.051	.0545	-.157	.056	.858	1	.354	.951	.854	1.058
ppt8_time	.194	.1221	-.045	.433	2.524	1	.112	1.214	.956	1.542
BMI_st	.156	.0652	.028	.283	5.706	1	.017	1.168	1.028	1.328
WC	-.046	.0207	-.087	-.005	4.936	1	.026	.955	.917	.995
age_calc	.041	.0319	-.021	.104	1.691	1	.194	1.042	.979	1.110
[edcat_2=1.00]	1.163	.5958	-.005	2.331	3.809	1	.051	3.199	.995	10.283
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1									

Dependent Variable: Specialist - frequent user
Model: (Intercept), timepoint, missing_rc, random, timepoint * random, num_gpvisits, income_2cat, num_cc, pcs_12, PASE_total, distance, chairstand, ppt8_time, BMI_st, WC, age_calc, edcat_2
a. Set to zero because this parameter is redundant.

Table C.13 Parameter estimates for the initial linear GEE model of log-transformed annual costs of specialist physician services

Parameter	B	Std. Error	95% Wald C.I.		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2.023	1.0066	.051	3.996	4.041	1	.044
[missing=5]	-.035	.1551	-.339	.269	.050	1	.822
[missing=4]	-1.446	.1550	-1.750	-1.143	87.072	1	.000
[missing=3]	-.112	.1708	-.447	.223	.430	1	.512
[missing=2]	-.105	.2028	-.502	.292	.268	1	.605
[missing=1]	.014	.1650	-.309	.337	.007	1	.933
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	-.006	.1613	-.322	.310	.001	1	.970
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	.241	.2765	-.301	.783	.762	1	.383
[timepoint=3]	-.168	.2274	-.614	.278	.546	1	.460
[timepoint=2]	.304	.1897	-.068	.676	2.569	1	.109
[timepoint=1]	.204	.1619	-.113	.521	1.588	1	.208
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	-.255	.3407	-.923	.413	.559	1	.455
[random=2] * [timepoint=3]	.427	.2800	-.122	.976	2.325	1	.127
[random=2] * [timepoint=2]	-.066	.2201	-.498	.365	.091	1	.763
[random=2] * [timepoint=1]	.244	.1820	-.113	.601	1.796	1	.180
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
num_gpvisits	.054	.0149	.025	.083	13.061	1	.000
num_spvisits	.048	.0227	.004	.093	4.501	1	.034
num_cc	.141	.0351	.072	.210	16.120	1	.000
pcs_12	.004	.0053	-.006	.014	.628	1	.428
age_calc	-.002	.0086	-.019	.015	.077	1	.782
[gender=1]	.105	.1331	-.156	.366	.624	1	.430
[gender=0]	0[a]	.	.	.	.	.	.
[edcat_2=1.00]	-.380	.1610	-.696	-.065	5.580	1	.018
[edcat_2=.00]	0[a]	.	.	.	.	.	.
[income_2cat=1.00]	-.195	.1377	-.465	.074	2.013	1	.156
[income_2cat=.00]	0[a]	.	.	.	.	.	.
distance	.000	.0012	-.003	.002	.057	1	.812
PASE_total	-7.909E-005	.0007	-.001	.001	.013	1	.910
sed_week	.008	.0059	-.003	.020	1.936	1	.164
chairstand	-.052	.0179	-.087	-.017	8.571	1	.003
armcurl	.005	.0103	-.015	.026	.283	1	.595
ppt8_time	.029	.0319	-.033	.092	.832	1	.362
(Scale)	.729						

Dependent Variable: transformed sp costs

Model: (Intercept), missing, random, timepoint, random * timepoint, num_gpvisits, num_spvisits, num_cc, pcs_12, age_calc, gender, edcat_2, income_2cat, distance, PASE_total, sed_week, chairstand, armcurl, ppt8_time

a. Set to zero because this parameter is redundant.

Table C.14 Parameter estimates for the final linear GEE model of log-transformed annual costs of specialist physician services

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2.059	.4054	1.264	2.853	25.793	1	.000
[missing=5]	-.030	.1390	-.302	.242	.047	1	.829
[missing=4]	-1.407	.1201	-1.642	-1.172	137.293	1	.000
[missing=3]	-.113	.1657	-.438	.212	.466	1	.495
[missing=2]	-.119	.2088	-.528	.291	.322	1	.570
[missing=1]	.014	.1588	-.297	.326	.008	1	.928
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	-.002	.1524	-.300	.297	.000	1	.992
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	.215	.2525	-.280	.710	.727	1	.394
[timepoint=3]	-.198	.2214	-.632	.236	.803	1	.370
[timepoint=2]	.249	.1724	-.089	.587	2.093	1	.148
[timepoint=1]	.158	.1509	-.137	.454	1.103	1	.294
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	-.258	.3142	-.873	.358	.672	1	.413
[random=2] * [timepoint=3]	.483	.2656	-.038	1.003	3.304	1	.069
[random=2] * [timepoint=2]	-.008	.2156	-.431	.414	.001	1	.969
[random=2] * [timepoint=1]	.231	.1752	-.113	.574	1.734	1	.188
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
num_gpvisits	.052	.0154	.021	.082	11.261	1	.001
num_spvisits	.050	.0236	.003	.096	4.441	1	.035
num_cc	.131	.0342	.065	.198	14.823	1	.000
[edcat_2=1.00]	-.319	.1602	-.633	-.005	3.961	1	.047
[edcat_2=.00]	0[a]	.	.	.	.	.	.
chairstand	-.051	.0142	-.079	-.023	12.919	1	.000
pcs_12	.002	.0050	-.008	.012	.176	1	.675
[income_2cat=1.00]	-.186	.1262	-.434	.061	2.184	1	.139
[income_2cat=.00]	0[a]	.	.	.	.	.	.
ppt8_time	.033	.0277	-.021	.087	1.431	1	.232
(Scale)	.719						

Dependent Variable: transformed sp costs
Model: (Intercept), missing, random, timepoint, random * timepoint, num_gpvisits, num_spvisits, num_cc, edcat_2, chairstand, pcs_12, income_2cat, ppt8_time
a. Set to zero because this parameter is redundant.

Table C.15: Parameter estimates for the initial binomial (logit) GEE model of hospital admissions

Parameter	B	Std. Error	95% Wald C.I.		Hypothesis Test			Exp(B)	95% Wald C.I. for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	.374	3.3304	-6.154	6.901	.013	1	.911	1.453	.002	993.283
[random=2]	-.064	.5908	-1.222	1.094	.012	1	.914	.938	.295	2.986
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4]	-.161	.7476	-1.627	1.304	.047	1	.829	.851	.197	3.683
[timepoint=3]	.751	1.3507	-1.896	3.398	.309	1	.578	2.119	.150	29.911
[timepoint=2]	-.638	.8312	-2.268	.991	.590	1	.442	.528	.104	2.693
[timepoint=1]	-.565	.6094	-1.759	.630	.859	1	.354	.568	.172	1.877
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.544	.5196	-1.562	.475	1.095	1	.295	.581	.210	1.607
[missing_rc=2.00]	-.364	.4729	-1.291	.563	.593	1	.441	.695	.275	1.756
[missing_rc=1.00]	-.277	.4116	-1.084	.530	.453	1	.501	.758	.338	1.699
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	-.150	1.0777	-2.262	1.962	.019	1	.889	.861	.104	7.114
[timepoint=3] * [random=2]	-1.878	1.3941	-4.611	.854	1.815	1	.178	.153	.010	2.349
[timepoint=2] * [random=2]	-.241	.9213	-2.047	1.564	.069	1	.793	.786	.129	4.780
[timepoint=1] * [random=2]	.052	.7392	-1.397	1.501	.005	1	.944	1.054	.247	4.486
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	-.090	.0503	-.188	.009	3.178	1	.075	.914	.828	1.009
num_spvisits	-.140	.1443	-.423	.142	.948	1	.330	.869	.655	1.153
num_cc	-.104	.2002	-.497	.288	.272	1	.602	.901	.609	1.334
age_calc	.007	.0234	-.039	.053	.098	1	.755	1.007	.962	1.055
[marital_2cat=1.00]	.281	.3166	-.339	.902	.790	1	.374	1.325	.712	2.464
[marital_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
[income_2cat=1.00]	.108	.4053	-.686	.903	.071	1	.789	1.114	.504	2.466
[income_2cat=.00]	0[a]	.	.	.	.	.	.	1	.	.
[edcat_2=1.00]	1.040	.3604	.334	1.747	8.332	1	.004	2.830	1.396	5.737
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
PASE_total	.004	.0032	-.002	.010	1.720	1	.190	1.004	.998	1.010
sed_week	-.031	.0183	-.067	.005	2.847	1	.092	.970	.935	1.005
MAP	.022	.0140	-.006	.049	2.399	1	.121	1.022	.994	1.051
distance	.000	.0029	-.005	.006	.004	1	.949	1.000	.995	1.006
chairstand	-.007	.0526	-.110	.096	.016	1	.900	.993	.896	1.101
armcurl	.005	.0365	-.067	.077	.019	1	.891	1.005	.936	1.080
ppt8_time	-.120	.1219	-.359	.119	.975	1	.323	.887	.698	1.126
(Scale)	1									

Dependent Variable: admitted to hospital - yes/no
Model: (Intercept), random, timepoint, missing_rc, timepoint * random, num_gpvisits, num_spvisits, num_cc, age_calc, marital_2cat, income_2cat, edcat_2, PASE_total, sed_week, MAP, distance, chairstand, armcurl, ppt8_time
a. Set to zero because this parameter is redundant.

Table C.16: Parameter estimates for the final binomial (logit) GEE model of hospital admissions

Parameter	B	Std. Error	95% Wald C.I.		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	5.903	1.8127	2.350	9.455	10.603	1	.001	365.976	10.482	12777.770
[random=2]	-.206	.6335	-1.447	1.036	.106	1	.745	.814	.235	2.817
[random=1]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4]	-.439	.8975	-2.198	1.320	.239	1	.625	.645	.111	3.744
[timepoint=3]	.458	1.2576	-2.007	2.923	.133	1	.716	1.581	.134	18.597
[timepoint=2]	-.994	.9022	-2.763	.774	1.215	1	.270	.370	.063	2.168
[timepoint=1]	-1.082	.7954	-2.641	.477	1.851	1	.174	.339	.071	1.611
[timepoint=0]	0[a]	.	.	.	.	.	.	1	.	.
[missing_rc=3.00]	-.677	.5079	-1.672	.319	1.776	1	.183	.508	.188	1.375
[missing_rc=2.00]	-.377	.4574	-1.273	.520	.679	1	.410	.686	.280	1.681
[missing_rc=1.00]	-.216	.4015	-1.003	.570	.291	1	.590	.805	.367	1.769
[missing_rc=.00]	0[a]	.	.	.	.	.	.	1	.	.
[timepoint=4] * [random=2]	.550	1.2180	-1.837	2.937	.204	1	.652	1.733	.159	18.858
[timepoint=3] * [random=2]	-2.002	1.3466	-4.642	.637	2.211	1	.137	.135	.010	1.891
[timepoint=2] * [random=2]	-.150	.9620	-2.035	1.736	.024	1	.876	.861	.131	5.673
[timepoint=1] * [random=2]	.319	.8319	-1.311	1.950	.147	1	.701	1.376	.269	7.026
[timepoint=0] * [random=2]	0[a]	.	.	.	.	.	.	1	.	.
num_gpvisits	-.111	.0549	-.218	-.003	4.068	1	.044	.895	.804	.997
num_spvisits	-.141	.1454	-.426	.144	.940	1	.332	.869	.653	1.155
num_cc	-.243	.2298	-.693	.207	1.118	1	.290	.784	.500	1.231
[edcat_2=.00]	0[a]	.	.	.	.	.	.	1	.	.
pcs_12	-.041	.0197	-.080	-.002	4.350	1	.037	.960	.923	.998
PASE_total	.005	.0030	-.001	.011	2.641	1	.104	1.005	.999	1.011
sed_week	-.022	.0176	-.057	.012	1.635	1	.201	.978	.945	1.012
ppt8_time	-.150	.1148	-.375	.075	1.712	1	.191	.861	.687	1.078
(Scale)	1									

Dependent Variable: admitted to hospital - yes/no

Model: (Intercept), random, timepoint, missing_rc, timepoint * random, num_gpvisits, num_spvisits, num_cc, edcat_2, pcs_12, PASE_total, sed_week, ppt8_time

a. Set to zero because this parameter is redundant.

Table C. 17: Parameter estimates for the initial linear GEE model of log-transformed annual costs of hospital services

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	.023	.8878	-1.717	1.763	.001	1	.979
[missing=5]	.185	.1547	-.119	.488	1.425	1	.233
[missing=4]	.274	.2022	-.122	.670	1.841	1	.175
[missing=3]	.264	.2032	-.134	.662	1.686	1	.194
[missing=2]	.320	.1810	-.035	.675	3.124	1	.077
[missing=1]	-.001	.1491	-.293	.292	.000	1	.997
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	.031	.1937	-.348	.411	.026	1	.872
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	.043	.2596	-.465	.552	.028	1	.867
[timepoint=3]	-.069	.2533	-.565	.428	.074	1	.786
[timepoint=2]	.245	.2915	-.326	.816	.706	1	.401
[timepoint=1]	.211	.2110	-.203	.624	.997	1	.318
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	-.134	.3507	-.822	.553	.146	1	.702
[random=2] * [timepoint=3]	.473	.3218	-.158	1.104	2.160	1	.142
[random=2] * [timepoint=2]	.077	.3480	-.605	.759	.049	1	.825
[random=2] * [timepoint=1]	-.009	.2554	-.509	.492	.001	1	.973
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
num_gpvisits	.056	.0160	.025	.087	12.336	1	.000
num_spvisits	.044	.0228	-.001	.088	3.696	1	.055
num_cc	.064	.0685	-.070	.198	.875	1	.350
age_calc	.002	.0078	-.014	.017	.048	1	.827
[edcat_2=1.00]	-.389	.1571	-.697	-.081	6.118	1	.013
[edcat_2=.00]	0[a]	.	.	.	.	.	.
[income_2cat=1.00]	-.169	.1602	-.483	.145	1.107	1	.293
[income_2cat=.00]	0[a]	.	.	.	.	.	.
MAP	-.009	.0042	-.017	.000	4.143	1	.042
distance	.000	.0009	-.001	.002	.249	1	.618
PASE_total	-.002	.0009	-.003	.000	2.978	1	.084
sed_week	.013	.0057	.002	.024	5.470	1	.019
chairstand	.012	.0157	-.019	.043	.593	1	.441
armcurl	.001	.0122	-.023	.025	.002	1	.965
ppt8_time	.087	.0477	-.006	.181	3.340	1	.068
(Scale)	1.160						

Dependent Variable: transformed hospital costs
Model: (Intercept), missing, random, timepoint, random * timepoint, num_gpvisits, num_spvisits, num_cc, age_calc, edcat_2, income_2cat, MAP, distance, PASE_total, sed_week, chairstand, armcurl, ppt8_time
a. Set to zero because this parameter is redundant.

Table C.18: Parameter estimates for the final linear GEE model of log-transformed annual costs of hospital services

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.310	.6535	-1.591	.971	.225	1	.635
[missing=5]	.065	.1380	-.206	.335	.221	1	.638
[missing=4]	.191	.1821	-.166	.548	1.096	1	.295
[missing=3]	.258	.2078	-.149	.666	1.544	1	.214
[missing=2]	.286	.1505	-.009	.580	3.601	1	.058
[missing=1]	.004	.1435	-.277	.285	.001	1	.978
[missing=0]	0[a]	.	.	.	.	.	.
[random=2]	.037	.1965	-.348	.422	.036	1	.850
[random=1]	0[a]	.	.	.	.	.	.
[timepoint=4]	.141	.2798	-.408	.689	.253	1	.615
[timepoint=3]	-.071	.2741	-.608	.467	.066	1	.797
[timepoint=2]	.308	.2880	-.256	.873	1.146	1	.284
[timepoint=1]	.368	.2363	-.095	.831	2.423	1	.120
[timepoint=0]	0[a]	.	.	.	.	.	.
[random=2] * [timepoint=4]	-.285	.3471	-.965	.396	.672	1	.412
[random=2] * [timepoint=3]	.539	.3327	-.113	1.192	2.629	1	.105
[random=2] * [timepoint=2]	.109	.3452	-.568	.786	.100	1	.752
[random=2] * [timepoint=1]	-.045	.2724	-.579	.489	.028	1	.868
[random=2] * [timepoint=0]	0[a]	.	.	.	.	.	.
num_gpvisits	.066	.0153	.036	.096	18.667	1	.000
num_spvisits	.037	.0200	-.002	.076	3.437	1	.064
[edcat_2=1.00]	-.345	.1446	-.629	-.062	5.705	1	.017
[edcat_2=.00]	0[a]	.	.	.	.	.	.
MAP	-.008	.0046	-.017	.001	3.321	1	.068
sed_week	.013	.0052	.003	.023	6.600	1	.010
num_cc	.108	.0710	-.031	.247	2.300	1	.129
pcs_12	.014	.0056	.003	.025	6.470	1	.011
[income_2cat=1.00]	-.159	.1550	-.463	.145	1.050	1	.306
[income_2cat=.00]	0[a]	.	.	.	.	.	.
PASE_total	-.001	.0008	-.003	.000	3.190	1	.074
ppt8_time	.083	.0412	.003	.164	4.113	1	.043
(Scale)	1.109						

Dependent Variable: transformed hospital costs
Model: (Intercept), missing, random, timepoint, random * timepoint, num_gpvisits, num_spvisits, edcat_2, MAP, sed_week, num_cc, pcs_12, income_2cat, PASE_total, ppt8_time
a. Set to zero because this parameter is redundant.